CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

Nondestructive Testing of concrete: An Annotated Bibliography, 1934-1974

by
N.G. Zoldners
and
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NON-DESTRUCTIVE TESTING OF CONCRETE: AN ANNOTATED BIBLIOGRAPHY, 1934 - 1974

N.G. Zoldners and J.A. Soles

MINERAL RESEARCH PROGRAM
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FOREWORD

Canada Centre for Mineral and Energy Technology (CANMET, formerly the Mines Branch) has been in the forefront of non-destructive testing of metals for over 40 years. During the past 20 years, these methods have also been applied to the testing of cementitious materials in general, and concrete in particular. As a result, considerable data and experience in the use of non-destructive techniques have accumulated. The information had been summarized in the 1968 Mines Branch Monograph 875, and a 16-mm colour movie of 30 minutes' duration was produced in 1980. Monograph 875 became the basis of the American Concrete Institute publication "Testing Hardened Concrete: Nondestructive Methods", issued in 1977.

As part of technology transfer and information dissemination, CANMET, in association with the American Concrete Institute, the National Bureau of Standards U.S.A. and the Canadian Society for Civil Engineering sponsored an international conference on In Situ Non-Destructive Testing of Concrete, which was held in Ottawa, Canada in 1984. The Proceedings of the conference are available from the American Concrete Institute as ACI SP-82. One of the papers included was the CANMET-sponsored Annotated Bibliography on Non-Destructive Testing of Concrete: 1975-1983, by N.G. Zoldners and J.A. Soles. That bibliography did not contain the papers presented at the 1984 Conference, so an updated version that included summaries of the ACI SP-82 presentations was prepared by the authors and issued in 1985 as a CANMET special publication, SP 85-5E. It was the first of a three-part bibliographic series on the non-destructive testing of concrete.

This current publication is the second of the series; it contains annotated abstracts of the international literature published in the period 1934-1974. The final issue, for the period 1985-1989, will follow shortly. It is hoped that this Bibliography will be of use to practising engineers, technologists and graduate students engaged in the testing of concrete and strength evaluation of concrete structures.

V.M. Malhotra
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PRÉFACE

Depuis plus de quarante ans, le Centre canadien de la technologie des minéraux et de l'énergie, CANMET, anciennement la Division des mines, a été à l'avant-garde en matière de méthodes d'essais non destructifs des métaux. Pendant les vingt dernières années, ces méthodes ont également été employées pour la vérification des matériaux à base de ciment en général, et des bétons en particulier. Par conséquent, beaucoup d'expérience et de données sur l'utilisation des méthodes d'essais non destructifs ont été accumulées. L'information est compilée dans la Monographie 875 publiée en 1968 par la Direction des mines, et un vidéo 16 mm en couleur, d'une durée de 30 minutes, a été produit en 1980. La Monographie 875 a servi de manuel de référence pour la publication, en 1977, par l'American Concrete Institute de "Testing Hardened Concrete : Nondestructive Methods".

En guise de contribution au transfert technologique et à la diffusion de l'information, CANMET, en collaboration avec l'American Concrete Institute, le National Bureau of Standards U.S.A. et la Canadian Society for Civil Engineering a parrainé une conférence internationale sur les essais non destructifs *in situ* du béton qui s'est tenue à Ottawa, Canada en 1984. Le recueil des comptes rendus de la conférence est disponible sous le titre ACI SP-82 auprès de l'American Concrete Institute. L'un des documents scientifiques inclus est la Bibliographie annotée sur les méthodes d'essais non destructifs : 1975-1983, par N.G. Zoldners et J.A. Soles dont la publication a été parrainée par CANMET. Les exposés présentés à la conférence de 1984 n'étant pas inclus dans la bibliographie, une version récente comprenant des résumés des exposés publiés dans ACI SP-82 a été préparée par les auteurs et publiée par CANMET, en 1985, comme publication spéciale, sous le titre SP85-5F. Elle constitue le premier volume d'une collection bibliographique en trois volumes sur les méthodes d'essais non destructifs du béton.

La présente publication est la deuxième de la collection; elle contient des résumés annotés de la documentation scientifique internationale publiée dans la période s'échelonnant de 1934 à 1974. Le dernier numéro couvrant la période de 1985 à 1989 sera publié sous peu. Nous espérons que cette bibliographie sera utile aux ingénieurs, techniciens et étudiants qui sont préposés aux essais du béton et à l'évaluation de la résistance des structures en béton.

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NON-DESTRUCTIVE TESTING OF CONCRETE:

AN ANNOTATED BIBLIOGRAPHY, 1934-1974

N.G. Zoldners and J.A. Soles

Synopsis

Non-destructive concrete testing methods provide construction engineers and concrete technologists with useful tools for quality control of concrete and for evaluating the strength and durability of existing structures. This annotated bibliography, the second of a three-part series, compiles international literature published from 1934 to 1974 on innovations and modifications of non-destructive methods used for the testing of concrete. Attention was focused on new methods, particularly ultrasonic pulse velocity, developed for monitoring strength development and deterioration of concrete, and the development of cracks.

The journals, symposia, and books selected for review have international stature and contain state-of-the-art experimental works from diverse laboratories. Authors' abstracts or their translations are included when possible, to assist the concrete engineer in determining the applicability of a method to provide needed data.

This study was made possible with a Canadian Government contract awarded to the senior author.

N.G. Zoldners, P.Eng., is a consulting materials engineer specializing in concrete technology. He has carried out extensive research on the properties and testing of concrete, and has published many papers on this subject in the ASTM, ACI, and other professional journals.

J.A. Soles, Ph.D., P.Eng., is a mineralogical research scientist with the Canada Centre for Mineral and Energy Technology (CANMET, EMR). He is involved with the study of reactive phases in concrete systems.

ESSAI NON DESTRUCTIF DU BÉTON

BIBLIOGRAPHIE ANNOTÉE, 1934-1974

N.G. Zoldners et J.A. Soles

Résumé

Les méthodes d'essai non destructif du béton constituent pour les ingénieurs civils et les techniciens du béton de précieux outils de contrôle de la qualité du béton et d'évaluation de la résistance et de la durabilité des ouvrages existants. Cette bibliographie annotée, deuxième d'une série de trois, est une liste des ouvrages internationaux publiés de 1934 à 1974 sur les innovations et les modifications des méthodes non destructives utilisées pour vérifier le béton. Les méthodes les plus récentes sont traitées plus en détail, notamment les techniques exploitant la fréquence de résonance et la vitesse d'impulsions ultrasonores qui ont été mises au point pour contrôler l'évolution de la résistance, la détérioration du béton et l'évolution des fissures.

Les revues, symposiums et ouvrages choisis pour fins d'examen sont reconnus internationalement et font état de travaux expérimentaux de pointe de divers laboratoires. Des résumés des auteurs ou leurs traductions sont inclus le cas échéant pour aider l'ingénieur en béton à déterminer si une méthode peut fournir l'information requise.

La présente étude a été rendue possible grâce à un contrat accordé par le Gouvernement canadien à l'auteur principal.

N.G. Zoldners, ing., est un expert-conseil en matériaux, spécialisé dans les techniques du béton. Il a fait beaucoup de recherche sur les propriétés et les essais du béton, et a publié de nombreux ouvrages sur le sujet dans des revues professionnelles (ASTM, ACI, etc.).

J.A. Soles, Ph.D., ing., est chercheur en minéralogie au Centre canadien de la technologie des minéraux et de l'énergie (CANMET, EMR). Il est engagé dans l'étude des phases réactives dans les systèmes à base de béton, notamment celles des agrégats et des adjuvants stabilisateurs.

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Keywords

Acoustical methods (emission, shock); break-off method; combined NDT methods; concrete cracking; concrete strength (compressive, flexural, tensile); delamination detection; durability measurement; electrical methods; electrical resistivity m.; electromagnetic m; gamma radiography; radiometry; infrared thermography; in situ NDT methods; magnetic methods; maturity technique; mechanical sonic pulse method; microwave absorption; nuclear test methods; pull-off methods; pulse echo technique; pulse velocity method; radar penetration technique; radioactive methods; radiation shielding tests; rebound hammer (Schmidt's); resonant frequency method; surface hardness methods; T.V. inspection method; ultrasonic pulse methods.

NONDESTRUCTIVE TESTING OF CONCRETE:
AN ANNOTATED BIBLIOGRAPHY,
1934 - 1974

1934

1. GAEDE, K., "Ein neues Verfahren zur Festigkeitsprüfung des Betons im Bauwerk (A new method for strength testing of concrete in the structure), "Der Bauingenieur", Berlin, Heft 35/36, Vol. 15, 1934, pp. 356-357.

Recognizing the need for a simple field test to evaluate the strength of concrete in structure, Dr. -Ing. K. Gaede carried out an investigation on hardness testing of concrete. He used a new ball impact test hammer (F-ma Fritz Werner) similar to the Brinell ball indenter used to evaluate tensile strength of metals. The ball impact hammer produced spherical indentations on the concrete surface, the diameter of which is related to compressive strength of concrete.

Keywords: NDT; ball impact hammer; ball indentation; concrete surface hardness; diameter of indentation; impact test; surface hardness test; Werner test hammer.

1936

2. WILLIAMS, J.P., "A method for the estimation of compressive strength of concrete in the field"; The Structural Engineer Magazine, July, 1936, pp. 321-326.

An indirect method of estimating the compressive strength of concrete, suitable for use in the field, is described. A gun type

instrument devised for impact testing on concrete surface is used. The principle of the method involves the measurement of ball indentation as in the Brinell test for metals. The impact is created with a suitable constant force by means of a spring. The diameter of the impression made is measured by a magnifying scale.

Keywords: NDT; ball impact gun; diameter of indentation; concrete surface hardness; surface resistance to impact; testing gun; Williams testing pistol.

1938

3. POWERS, T.C., "Measuring Young's modulus of elasticity by means of sonic vibrations"; Proc. ASTM, Vol. 38, 1938, pp. 60-469.

A dynamic method of measuring Young's modulus of elasticity of concrete or mortar specimens by determining its natural frequency of vibration is described. For the work reported the frequency was determined by finding the bar in a set of orchestra bells which gave the pitch nearest to that of the specimen when struck with a small hammer. A sonometer is perhaps the best instrument for this purpose, although a vacuum tube oscillator may also be suitable. Data are presented comparing the E moduli obtained by this method with those obtained by static loading methods. The dynamic method is believed to give the true elastic modulus, not influenced by plastic flow.

Keywords: concrete elastic properties; frequency of vibration; sonic modulus; Young's modulus of elasticity.

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4. SKRAMTAJEV, D.G., "Determining concrete strength for control of concrete quality in structures"; Journal of ACI, Vol. 34, Jan./Feb., 1938, pp. 255-303.

An extensive work on the methods of testing concrete in complete structures has been carried out in the USSR, (e.g. Inst. for Industrial Bldg. Research, Moscow). Intensive developments of such USSR methods dates from 1934, when the method of shooting with a revolver (Nagan Type), developed by this author, was published in "Stroitelnaja Promishlennostj", No. 3 and 12, 1934. Discussed are 14 different methods, of which 10 were developed in USSR. Of these, six require preparations when placing concrete, and eight apply to finished structures (Wolf's, Polizkov's, Pavlov's, Nielaender's methods).

Keywords: NDT; concrete strength control; bullet test; pullout test; impact test method; test hammer.

1940

5. THOMSON, W.T., "Measuring changes in physical properties of concrete by the dynamic method"; Proc. ASTM, Vol. 40, 1940, pp. 1113-1121. Disc. by G. Pickett, T.F. Willis and M.E. De Reus, pp. to 1159.

Determination of physical properties of concrete test specimens under cyclic freezing and thawing is accompanied by changes in modulus of elasticity and the decrement of vibration, both of which can be measured by the dynamic method. The natural frequency of vibration is related to the modulus E and the mass density; the damping capacity is related to the energy, dissipated by internal friction.

Keywords: deterioration of concrete; dynamic E modulus; natural frequency of vibration; damping capacity; mass density; logarithmic decrement of vibration.

1941

6. GAEDE, K., "Die Prüfung der Betonfestigkeit im Bauwerk" (Testing strength of concrete in the structure); Der Bauingenieur, Berlin, Heft 13/16, 1941, pp. 138-142.

Several proposed indirect test methods for strength determination of concrete in the structure are discussed.

A. Surface hardness tests producing indentations:
   1) by sustained pressure under controlled load;
   2) by dynamic impact of a steel ball, using -
      (a) a spring ball hammer instrument, as proposed by Gaede (1932), Bied, Giusti, Vandone-Itlay (1933/34), and Williams, U.K. (1936) and
      (b) a gun type instrument, as proposed by Skramtajev, USSR (1934) or Poliakov, USSR (1935).

B. Shear strength testing of concrete (Pavlov, Perfilieff, USSR).

C. Tensile strength of concrete: Pull-out (Wolf, Skramtajev, USSR).

D. Measuring deformation under sustained load (Nielaender, USSR).

Keywords: NDT: ball impact; ball spring hammer; concrete surface hardness; deformation under load; gun type tester; surface indentation; pull-out test; compressive strength; tensile strength; shear strength.

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7. OBERT, L. and DUVALL, W.I., "Dynamic methods of testing concrete with suggestions for standardization"; Proc. ASTM, Vol. 41, 1941, pp. 1053 - 1071. Discuss. by G. Pickett.

To assist in standardizing the dynamic methods of testing concrete, the underlying theory, apparatus, effect of moisture, and size of specimens have been studied and the findings presented herein. A discussion of the apparatus used in measuring both modulus of E and the damping constant Q is included with suggestions for improving its accuracy. Test results indicate that both modulus E and, in particular, the damping constant Q vary with the water content of the specimen.

Keywords: NDT; concrete strength; E modulus; damping constant Q; dynamic test methods; moisture effect; physical constants.

1944

8. TREMPER, B., "The measurement of concrete strength by embedded pull-out bars"; Proceedings ASTM, Vol. 44, 1944, pp. 880 - 887.

This paper reports the results of a lab. investigation in which 120 pull-out tests specimens and 120 cylinders were cast from 30 batches of concrete. Mixes and test ages were varied over usable ranges. The coeff. of variation of pull-out tests was only slightly greater than that of compr. strength tests. A high degree of correlation exists between the two tests. The method does not appear to be suitable for concrete of higher strength than 3500 psi. The field tests can be made with a dynamometer or a gage-equipped hydraulic jack. This test has the advantage of giving direct indication of the strength of the concrete in the structure.

Keywords: concrete compr. strength; pull-out test; NDT for field uses.

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9. YOUNG, R.B., "A device for determining the depth of surface cracks in concrete"; Journal ACI, Proc. Vol. 40, 1944, pp. 401 - 408.

A device is described consisting essentially of a pressure tank, an air pump and a pressure gage, together with pipes, valves and fittings by which a dye solution is forced into the crack to be explored. Then by drilling, the crack is followed inward to the bottom. The depth of the crack is established by a pressure test.

Keywords: concrete; crack; depth; dye; pressure tank.

1945

10. LONG, B.G., KURTZ, H.J. and SANDENAW, T.A., "An instrument and a technique for field determination of the modulus of elasticity and flexural strength of concrete (Pavements)"; Journal ACI, Proc. Vol. 41, 1945, pp. 217 - 232.

An instrument for in-situ determination of the dynamic modulus of elasticity of concrete is described. Test results are presented which show (a) the comparison of test values of E, obtained by various older methods, with that obtained with the new instrument; and (b) the relationship of such values to the flexural strength of concrete. It is concluded that adoption of the new method and technique is justified.

Keywords: NDT; dynamic testing method; dynamic E; flexural strength; wave velocity; electronic interval timer; compressive strength.

1946

11. HUMMEL, A. and CHARISIUS, K., "Baustoffprüfungen" (A book with guidelines for testing non-metallic inorganic building materials); Publ. Verlagsgesellschaft mbM Max Lipfert, Berlin, Nov. 1946, 312 pp. (in German).

Book provides information on test methods for cement, lime, gypsum and other binders; test on slag, trass and chemical additives; tests on lime mortar, cement mortar, concrete mixes; tests on aggregates; tests on hardened concrete - compressive, flexural and tensile strength; as a new test method - nondestructive test for surface hardness, using the Gaede spring hammer and measuring ball indentation diameter.

Keywords: testing aggregates; cement; gypsum; lime concrete; cellular concrete; lightweight aggregate concrete; sand; stone; bricks; concrete blocks.

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12. PREECE, F.E., "The use of the dynamic modulus of elasticity in predicting the 28-day flexural strength of concrete", Proc. ASTM, Vol. 40, 1946, pp. 1311 - 1319.

For a given set of conditions there is a relationship between the dynamic E and the age of a concrete test specimen; in addition, the dynamic E and the coincident flexural strength are related. Thus, the modulus provides a means for predicting the 28-day flexural strength of concrete when it is but a few days old.

Keywords: dynamic testing; NDT method, dynamic modulus of E; flexural strength.

1949

13. ASTM, Symposium on Ultrasonic Testing; 52nd annual meeting of ASTM, Atlantic City, N.J., June 28, 1949; ASTM Spec. Tech. Publ. No. 101 (133 pp.).

The ten papers and discussions included in this volume represent a summary of the history, theoretical aspects, basic principles of practical testing and applications of ultrasonic testing. A paper by J.R. Leslie (Hydro-El. Power Commission of Ontario) "Pulse techniques applied to dynamic testing" (pp. 104-116) presents an electronic pulse test set developed primarily for testing concrete structures in the field. A pulse generator and receiver are used, applied to opposite faces of the structure. The time of travel of the pulse is measured on a cathode ray tube using a strobe circuit and reading dial.

Keywords: NDT; dynamic testing; sound waves; propagation of waves; ultrasonic waves; pulse velocity.

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14. ASTM, Symposium on Dynamic Stress Determinations; Pacific area national meeting of ASTM, San Francisco, Cal., Oct. 11, 1949. ASTM Spec. Techn. Publ. No. 104 (60 pp.).

The general problem of making and interpreting dynamic measurements has been divided into its elements by considering separately 1) basic pick-up units, 2) recording systems operated from the output signal of the pick-up unit, and 3) analysis and interpretation of such records. A paper by Douglas McHenry (U.S. Bureau of Reclamation, Denver, Colo.) "Examples of Dynamic Testing in the Field of Structures and materials", describes various test methods used, such as the hammer method, the seismic method and other dynamic test methods. For E modulus determination in concrete,

sonic methods and also ultrasonic pulse velocity measurements are being used.

Keywords: NDT; dynamic testing; seismic method; sonic method; ultrasonic pulse velocity.

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15. JONES, R., "Measurement of the thickness of concrete pavements by dynamic methods: a survey of the difficulties"; Magazine of Concrete Research, Vol. 1, No. 1, Jan. 1949, pp. 31 - 34.

Errors occur in the determination of the thickness of imperfectly compacted slabs when a variation of sound velocity occurs with depth in the slab, but calculations are given which show that the method based on reflection of an ultrasonic pulse by the bottom of the slab could be made to yield accurate results, should the present experimental difficulties be overcome.

Keywords: NDT method; concrete slab; reflected pulse; longitudinal vibration; sound waves; thickness of the slab; ultrasonic pulse velocity.

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16. JONES, R., "The non-destructive testing of concrete"; Magazine of Concrete Research, Vol. 1, No. 2, June 1949, pp. 67 - 76.

The value of the longitudinal wave velocity as an index of concrete quality is discussed, with reference to tests made on a variety of specimens subsequently subjected to compr. and flex. strength tests and density analysis. Deterioration of concrete quality due to freezing and thawing can be detected before superficial damage occurs. The Poisson's ratio of several types of concrete has been measured and values obtained from 0.16 to 0.31, depending mainly upon the type of aggregate.

Keywords: NDT method; longitudinal wave velocity; concrete; compressive strength; flexural strength; Poisson's ratio; concrete deterioration; ultrasonic pulse velocity.

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17. JONES, R. and GATFIELD, E.N., "A method of measuring ultrasonic pulse velocities"; Magazine of Concrete Research, Vol. 1, No. 2, June, 1949, pp. 77 - 78.

The method was developed for the determination of the longitudinal wave velocities in concrete specimens and consists of measuring the time taken for an ultrasonic pulse to pass through a known length of concrete. The main feature of the design of the apparatus is the high accuracy of measurement by which individual times of transmission may be measured to an accuracy of better than 1 per cent.

Keywords: NDT method; concrete quality; longitudinal wave velocities; ultrasonic pulse velocity; transmitter driver; transducer; vibrations; fundamental frequency.

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18. KLEINLOGEL, A., "Zur Frage der zerstörungsfreien Prüfung von Beton im fertigen Bauwerk" (Use of nondestructive testing on concrete structures); "Betonstein Zeitung", Heft 2, 1949, pp. 17 - 21.

This paper discusses several mechanical devices developed in Germany for surface hardness testing of concrete structures. Those are the Gaede ball impact spring hammer (Gaede applied for patent in 1932), the Einbeck pendulum hammer, and also the manual blow hammer. All are based on steel ball indentation measurements on a concrete surface, caused by the impact. These tests shall not replace the standard concrete specimen crushing test, but may be

used as supplementary tests in field for strength evaluation of concrete, as correlated with surface hardness measurements.

Keywords: NDT; ball spring hammer; ball blow hammer; Einbeck pendulum hammer; Gaede spring hammer; surface hardness.

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19. LESLIE, J.R. and CHEESMAN, W.J. "An ultrasonic method of studying deterioration and cracking in concrete structures", Journal of ACI, Vol. 46, Sept. 1949, pp. 17-36.

A new method and apparatus for field and laboratory testing of concrete designed by HEPC of Ontario, is described. The soniscope was originally designed to detect internal cracks in concrete. It develops ultrasonic pulses and measures their velocity. It is independent of the size or shape of the body under test. The velocity has been found to be a reliable measure of the condition of the concrete and is particularly useful in deterioration studies. The dynamic modulus of E can be calculated from the velocity.

Keywords: concrete; cracks; deterioration; pulse velocity; soniscope; ultrasonic test method.

1950

20. CHEFDEVILLE, J. and DAWANCE, G., "L'auscultation dynamic du beton" (Dynamic sounding of concrete); Annales de L'Institut Technique de Batiment et des Travaux Publics, Paris, France, No. 16, July-August 1950.

This report is the result of five years' research and development in the the Lab. du Batiment et des Trav. Publics (LBTP). The speed of sound between two quartz points placed on the surface of

concrete is measured. The time of propagation is read directly on the oscillograph in graduations of 5 sec. Modulus of E can be determined and compr. strength calculated for concrete at different hardening stages. There is a relation between compressive strength and dynamic modulus E.

Keywords: NDT; dynam. modulus of E; compression strength; sound propagation; quartz transducer; sound velocity.

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21. GOODELL, C.E. "Improved sonic apparatus for determining the dynamic modulus of concrete specimens"; ACI Journal, Vol. 47, No. 1, Sept. 1950, pp. 53 - 60.

A sonic apparatus developed for the Michigan State Highway Department is described. Reliable results can be obtained by an unskilled worker with this equipment. A wiring diagram of the sonic apparatus is included.

Keywords: sonic tests; fundamental resonant frequency; dynamic modulus of elasticity.

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22. LESLIE, J.R. and CHEESMAN, W.J. "Soniscope for examining concrete structures. Ultrasonic method detects cracks and deterioration", Hydro Research News (Ontario), Vol. 2, No. 1, Jan./March, 1950, pp. 1 - 4.

A new method and apparatus, called a Soniscope, for both field and laboratory testing of concrete have been developed by the Research Division of the Hydro-Electric Power Commission of Ontario. It seems to be suitable for determining the depth of surface cracks in and the dynamic modulus of elasticity of concrete dams.

Keywords: concrete cracks; depth of cracks; E modulus; pulse velocity; soniscope.

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23. LESLIE, J.R., "Pulse techniques applied to dynamic testing"; ASTM Proc. Vol. 50, 1950.

The use of a pulse technique for dynamic testing of material is proposed. The pulse velocity is unaffected by size or shape of the specimen, and the E modulus may be calculated. This test is developed primarily for testing deterioration and cracking of concrete structures.

Keywords: NDT; acoustical pulse technique; pulse velocity; ultrasonic test method; dynamic E modulus.

1951

24. ASTM, "Tentative Method of Test for Fundamental Transverse Frequency of Concrete Specimens for Calculating Young's Modulus of Elasticity (Sonic Method)"; Designation: C 215-51, T, 1951 Supplement of Book of ASTM Standards, Pt 3.

This Tentative was revised in 1952 and replaced by "Tentative Method of Test for Fundamental Transverse and Torsional Frequencies of Concrete Specimens", Design.: C 215-52 T, 1952 Book of ASTM Standards, Part 3. In the 1955 revision, "Longitudinal Frequencies" was added to the title. Final adoption of the standard was in 1960; it appears in the 1960 Book of Standards, Part 4.

Keywords: sonic tests; dynamic properties; fundamental frequency; longitudinal freq.; torsional freq.; transverse freq.

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25. CHEESMAN, W.J., "Soniscope studies on concrete during setting period", Hydro Research News (Ontario), Vol. 3, July-Sept., 1951, pp. 8 - 11.

The rate of hardening and the early-age strength pattern of concrete were studied. A series of measurements of ultrasonic pulse velocities in the concrete was made by a soniscope. It revealed that a good correlation existed between the compressive strength and pulse velocity.

Keywords: concrete hardening; fresh concrete; concrete strength; NDT; pulse velocity; ultrasonic tests.

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26. CHEESMAN, W.J. "Soniscope tests of concrete at early ages"; Research Report VLO 41111 & 2820-06 by Research Panel No. 20, The Hydro-Electric Power Commission of Ontario, Nov. 7, 1951.

A report on soniscope tests of concrete at early ages was conducted for guidance in the concreting of the hydraulic tunnel for Sir Adam Beck Niagara Generating Station No. 2. Investigated was the possibility of using pulse velocity to determine when concrete has developed adequate strength to allow safe stripping of formwork.

Keywords: strength of new concrete; pulse velocity; NDT; ultrasonic tests; form stripping time.

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27. GAEDE, K., "Uber die Bestimmung der Festigkeit des Betons" (Strength determination of concrete); Beton- und Stahlbeton-bau, Heft 7, 1951, pp. 155 - 159, Berlin.

Determination of compressive strength of concrete as per DIN 1048 - 1 from cube test samples for a building is discussed. Distribution of over 200 test results are shown on a Gaussian curve and

statistically analyzed for the concrete quality control. Recognizing the need for a non-destructive test method to be used on a structure, an investigation was initiated at the Deutsche Ausschuss für Stahlbeton in 1943 by Prof. K. Gaede, to develop an indirect method for strength evaluation from surface hardness tests. The Frank spring hammer and Einbeck pendulum hammer were used in this project.

Keywords: NDT; compressive strength of concrete; ball impact indentation; Frank spring hammer; Einbeck pendulum hammer.

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28. HERZIG, E., "Versuche mit dem neuen Beton-Prüfhammer an der Abteilung für Beton und Eisenbeton der Eidg. Materialprüfungsund Versuchsanstalt, Zürich (EMPA)" (Tests carried out with the new concrete test hammer at the EMPA, Zürich, Switzerland); Schweizer Archiv für angew. Wissenschaft und Technik, Vol. 17 (5), 1951, pp. 144 - 146.

The rebound test hammer used in this investigation is described in details by its inventor E. Schmidt, (see No. 31 below). Ten rebound readings were made on the vertical side of a test cube and the average value calculated. This was correlated with the compressive strength of the cube under test. 550 tests were produced. The effect of cement content, curing condition and age was noted.

Keywords: concrete compressive strength; hardness; ball indentation; Einbeck pendulum hammer; hand activated hammer; Frank spring hammer.

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30. EISENMANN, K., "Untersuchung der Rissebildung des Betons mit Ultraschall" (Crack detection in concrete by ultrasound); Beton und Stahlbetonbau, Vol. 46 (1), Jan. 1951, pp. 10 - 20.

In the Phys.-Techn. Institute in Hamburg tests were made on reinf. beams, showing that cracks in concrete reduce the intensity of ultrasound propagation. It was found that by increasing the load, concrete crack development can be noted from the rapid reduction in the intensity of ultrasound. This in turn indicates the quality of concrete itself.

Keywords: concrete; cracks; intensity of ultrasound; concrete quality; critical load; u/s velocity measurements.

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31. SCHMIDT, E., "Versuche mit dem neuen Beton-Prüfhammer zur Qualitätsbestimmung des Betons" (Tests with the new rebound test hammer to determine the quality of concrete); Schweizer Archiv für Angew. Wissenschaft und Technik, Vol. 17 (5), 1951, pp. 139 - 143.

In this article, a detailed description and application of a new concrete test hammer that measures the rebound value on concrete in structure is given. E. Herzig had described this test method as used at the EMPA projects to evaluate the properties of hardened concrete, establishing a relationship between rebound value and compressive strength of 20-cm concrete cubes. A statistical analysis of 550 tests is produced. Guidelines for use of the rebound test hammer are given.

Keywords: concrete; compressive strength; impact test; rebound test hammer; Schmidt test hammer; dispersion of rebound readings.

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32. WHITEHURST, E.A., "Use of soniscope for measuring setting time of concrete"; ASTM Proc. Vol. 51, 1951, pp. 1166 - 1175.

By observing the rate of change of the pulse velocity in fresh concrete the setting time may be determined.

Keywords: NDT; pulse velocity; setting time; ultrasonic tests; strength of concrete.

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33. WHITEHURST, E.A., "Soniscope tests concrete structures", ACI Journal, Vol. 47, No. 6, 1951, pp. 433 - 444.

A soniscope has been developed by the Hydro-Electric Power Commission of Ontario that measures group pulse velocities through as much as 50 ft of concrete. It was used for field testing by PCA since 1947 on 13 bridges, one navigation lock, 14 dams and five highway pavements in 12 states. Repeated tests permitted study of changes in the condition of the concrete and the development of group velocities indicating the condition of the structure.

Keywords: NDT; concrete deterioration; concrete strength; pulse velocity; ultrasonic tests; soniscope tests.

1952

34. ANDERSEN, J. and NERENST, P., "Wave velocity in concrete", ACI Journal, Vol. 48, No. 8, Apr. 1952, pp. 613 - 636.

A Danish timing device and its application to determine the wave velocity in concrete specimens is described. A hypothesis for the relation between wave velocity and age is presented. The method has been used on concrete in situ, including measurements of concrete members damaged by exposure to fire or freezing at early age.

Keywords: dynamic test method; non-destructive test; pulse velocity; wave velocity.

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35. ASTM, "Symposium on Non-Destructive Testing", 55th annual meeting of ASTM, New York, N.Y., June 26, 1952. Spec. Techn. Publ. No. 145 (brochure, 98 pp.).

In this Symposium on Non-Destructive Testing, the ASTM is presenting to its membership the advanced nondestructive testing methods and techniques in use throughout the world. The Symposium was initiated by Committee E-7 to acquaint the membership with the latest developments in non-destructive testing in Europe and Canada. Papers include descriptions of radiography, fluoroscopy and ultrasonic pulse methods with practical application for NDT purposes in metal testing.

Keywords: NDT; gamma rays; X-rays; radiography; fluoroscopy; pulse waves; ultrasonic pulse velocity.

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36. BRITISH STANDARDS INSTITUTION: "Methods of Testing Concrete"; British Standard 1881:1952, 62 p. booklet, publ. in London, England, July 1952.

Part 14. Determination of the modulus of elasticity by an electrodynamic method, namely by measuring the natural frequency of the fundamental mode of longitudinal vibration of concrete prisms.

Keywords: concrete mix; slump test; unit weight; compressive strength; flexural strength; modulus of elasticity; fundamental longitudinal frequencies.

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37. GAEDE, K., "Die Kugelschlagprüfung von Beton" (Ball-impact test of concrete), Deutscher Ausschuss für Stahlbeton, No. 107, 1952, pp. 15 - 30.

The ball-impact method used for hardness determination of concrete is described. The steel ball impact-produced indentation is measured and correlated with the corresponding cube strength. With an Einbeck pendulum hammer using gravity force at a half or full height, a ball of 25 mm dia. produces indentations ranging from 7 to 14 mm. across. A Frank spring hammer consists of a spring-controlled mechanism activating a plunger movement; a 10 mm dia. steel ball indents a concrete surface 4 to 7 mm across.

Keywords: NDT; concrete hardness; ball indentation; pendulum hammer; spring hammer.

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38. HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO, "Standard acoustic delay line for the soniscope", Ontario Hydro Research News, Vol. 4, No. 3, July/Sept. 1952, 6 pp.

A copper wire acoustic delay line has been constructed for use as a standard test specimen for the soniscope.

Keywords: acoustic delay; pulse velocity; copper wire.

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39. MARGARIT, A., "Nuevo método para la medición de módulos de elasticidad y posibilidad du su aplicación a los hormigones" (A new method of measuring the modulus of elasticity and its possible application to concrete) "Rivista de Giencia Aplicada" (Madrid), Vol. 6, Jan./Feb, 1952, pp. 28 - 31. Publ. also in Cemento - Hormigón (Barcelona), Vol. 18, No. 200, November 1950, pp. 345 - 350.

The author has developed an ingenious system, applied up to now solely for E modulus determination for metals, based on a synchronized pendulum system. He describes in detail similar apparatus constructed at the Institute of Techn. Invest., Barcelona for use on concrete E modulus.

Keywords: concrete, modulus of E; pendulum synchronized system.

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40. MEYER, R. C., "Dynamic testing of concrete pavement with the soniscope"; Proceedings, Highway Research Board, Vol. 31, 1952,

Kansas Highway Commission has been conducting extensive investigations of concrete pavements since 1949. Eight experimental pavements have been constructed, each made up of a number of test sections of varying composition. The strength-gaining qualities of the various types of concrete were studied. Sound pulse velocity measurements have been made periodically with the soniscope, and velocity history maintained. It is believed that changes in the modulus of elasticity and hance the pulse velocity indicate changes in quality of concrete.

Keywords: concrete pavements; dynamic testing; dynamic E-modulus; soniscope; pulse velocity; Young Young's modulus; quality changes.

1953

41. BATCHELDER, G.M. and LEWIS, D.W., "Comparison of dynamic methods of testing concretes subjected to freezing and thawing", ASTM Proc., Vol. 53, 1953, pp. 1055 - 1064; discussion - pp. 1065 - 1067.

The results of resonant frequency and pulse velocity (soniscope) tests on concretes subjected to freezing and thawing are discussed and compared.

Keywords: non-destructive testing; pulse velocity; resonant frequency; freezing and thawing test of concrete; compressive strength of concrete; modulus of elasticity.

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42. JONES, R., "The testing of concrete by an ultrasonic pulse technique", Proc., Highway Research board, Vol. 32, pp. 258 - 275.

This is a review of the work at the Road Research Laboratory. A description is given of the apparatus for making high precision measurements of the velocity of an ultrasonic pulse in concrete. It cannot be used as a criterion for modulus of rupture, compressive strength and density of concrete, due to the large number of variables. Where test specimens of structural concrete are available, a calibration curve can be obtained, from which equivalent strength of concrete can be inferred. In the laboratory, application of this technique has been used to study crack formation (a) under load, (b) subjected to frost action and (c) when inversion takes place in high-alumina cement.

Keywords: concrete; cracking; pulse velocity; NDT method.

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43. KESLER, Clyde, E. and HIGUCHI, Yo., "Determination of compressive strength of concrete using its sonic properties", ASTM Proc. Vol. 53, 1953, pp. 1044 - 1051.

The prediction of concrete strength usually is based on the initial modulus of elasticity. However, an additional property of concrete, the damping capacity, must also be considered; it can be obtained from the sonic tests.

Keywords: concrete strength; compressive and flexural strength; u/s pulse velocity; N-D tests of concrete.

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44. PARKER, W.E. "Pulse velocity testing of concrete", ASTM Proceedings, Vol. 53, 1953, pp. 1033 - 1042.

This is a review of the continuing use of the soniscope by the Hydro-Electric Power Comm. of Ontario, showing the fields in which it is finding it sgreatest usefulness and indicating the limitations that have been encountered. It describes its application for surveys of cracks in massive hydraulic structures, durability or condition surveys of old structures, the study of early strength development in concrete, and lab. studies involving concrete elastic and mechanical properties.

Keywords: concrete testing; non-destructive testing; pulse volocity; durability survey; crack survey.

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45. TYE, R.V., CALLAN, E.J. and ROSHORE, E.C., "Comparative tests of soniscopes for ultrasonic testing of concrete", Waterways Experiment Station (WES), Vicksburg, Miss., Misc. Paper No. 6 - 48, Sept. 1953, 30 pp.

Comparative tests of various models of the soniscope were conducted primarily to determine their reproducibility in measuring the pulse velocity of various concretes and, in addition, the effect different operators have on the measurement of pulse velocities. Representatives of PCA, OHEPC and WES, using their models of

soniscope, participated in the field testing concrete of the Tuscaloosa Lock, Alabama. Variations in results between the three units was about 2%. The three soniscopes were used also at the WES laboratory.

Keywords: concrete; cracks; deteriorated concrete; NDT; pulse velocity; path length; soniscope.

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46. WESCHE, K. "Betonprufüng mit Hilfe von Ultraschall" (The ultrasonic testing of concrete); Beton und Stahlbetonbau, Vol. 48 (5), May 1953, pp. 116 - 119.

In this article is discussed the determination of dynamic E modulus by measuring longitudinal, transverse frequencies in concrete test specimens, the use of ultrasonic pulse velocity measurements in field to detect cracks and faults in concrete, and the relationship of pulse velocity and compr. strength of concrete as affected by different factors and concrete mix quality. The relationship between u/s pulse velocity and flexural strength of concrete is also discussed.

Keywords: concrete strength; compressive and flexural strength; u/s pulse velocity; N-D tests of concrete.

1954

47. ARDEVOL, J.M., "La medida del modulo de elasticidad de los materiales par methodos vibratorios. Su aplicacion como metodo de control en las construciones de hormigon, y en los laboratorios de ensaya" (Determining the modulus of elasticity of materials by vibratory methods. Application of this method as a control method on concrete construction and in testing laboratories); Cemento - Hormigon (Barcelona), Vol. 22, 1954;

July, pp. 293 - 300; Aug. No. 245, pp. 336 - 343; Sept. No. 246, pp. 376 - 382; Oct. No. 247, pp. 413 - 420.

In this paper the author has discussed dynamic methods used in testing concrete. Those are: a) Resonant frequency method; b) Sonic pulse velocity (mechanical blow pulse method); c) Explosives detonation vibration velocity measurements, for use in concrete masses over 20 m thick.

Keywords: NDT of concrete; dynamic tests; pulse velocity; ultrasonic pulse velocity; dynamic modulus of elasticity.

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48. BREUNING, S.M. and BONE, A. J., "Soniscope applied to maintenance of concrete structures", Highway Research Board, N.R.C., Washington, D.C., Proc. Vol. 33, 1954, pp. 210 - 216. (Joint Highway Research Project, MIT).

Soniscope measures the time of a shock wave sent through the concrete, from which the velocity can be computed. This velocity represents a measure of the quality of material. Testing techniques for various types of structures are discussed. The results of these tests indicate that the soniscope can be a valuable supplement to visual inspection.

Keywords: compressive strength of concrete; density; deterioration; detection of cracks; pulse velocity; shock waves; soniscope; wave velocity.

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49. DIN 4240, "Richtlinien für die Anwendung der Kugelschlagprüfung von Beton mit dichtem Gefüge" (Guidelines for the use of Ball-Impact test of dense concrete), Sept. 1954 (Further edition April 1963).

This standard covers non-destructive concrete hardness tests on existing structures and structural parts. Hardness of the concrete surface is used as an indirect indication of compressive strength for 28-d. age. The concrete hardness is measured by the diameter of indentation by a 25 mm dia. steel ball under impact caused using a constant gravity force (Einbeck pendulum hammer), or with a spring loaded hammer (Frank spring hammer) with 10mm dia. steel ball. The size of indentation is a measure of hardness. To measure, a 6x magnifying glass and a 1/10 mm scale are used. A correlation is established with compressive strength.

Keywords: NDT method; concrete hardness; Einbeck pendulum hammer; Fran spring hammer; ball indentation.

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50. EISENMANN, K. and STEINKAMP, G. "Messung der Tiefen und Weiten von Betonrissen mittels Ultraschall" (Measuring crack depth and width in concrete using ultrasound), Beton- und Stahlbetonbau, Vol. 49 (2), Feb. 1954, pp. 36 - 38. (Tech. Univ., Braunschweig).

It is shown that the depth, and for the first time also the width, of cracks in concrete, measured by ultrasound, was d_R = 0.22 mm, whereas the same calculated was 0.21 mm. Reduction in the pulse velocity begins with microcracking, before even a visible crack on the surface appears.

Keywords: NDT of concrete; crack in concrete; detection of cracks by ultrasonic testing; depth of crack; cracks due to flexural stresses; effect of reinforcement on ultrasound velocity.

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51. GOLDSTEIN, S.J. and KITTRELL, F.W., "Radioisotope technique in concrete research:, ACI Journ., Vol. 50, No. 5, 1954, 393 pp.

The writers proposed some applications of radioisotopes as a research tool in exploring the strength, density, permeability, dimension stability and resistance to deterioration of concrete. Some topics which might be explored by "radioisotope-tagged material" are given.

Keywords: admixture; aggregates; concrete; density; radioisotopes; mixer efficiency; surface cracks; strains.

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52. GREENE, G.W., "Test hammer provides new method of evaluation hardened concrete", ACI Journ. Proc. Vol. 51, No. 3, Nov. 1954.

The Schmidt concrete test hammer provides a convenient method of determining the strength of concrete that has a smooth, flat surface. The test is nondestructive. Results of test made with the instrument are compared with results of compression and flexure tests. Factors causing variation in results are discussed briefly and the accuracy of the test hammer is compared with that of testing machine. Discussions: V. 51, No. 11, Dec. 1955.

Keywords: concrete; compressive strength; field testing; impact test; rebound hammer; surface hardness; trouble shooting; strength growth; Schmidt test hammer.

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53. MATHER, B., "Comparative tests of soniscope", Highway Research Board, NRC, Washington, D.C., Proc. Vol. 33, 1954, pp. 217-226.

Comparative tests were made in May, 1952 at Tuscaloosa, Alabama, by representatives of the Corps of Engineers, Portland Cement Association and Hydro-Electric Power Commission of Ontario, with

soniscopes used by each organization. Comparative determinations of pulse velocities were made at stations in the Tuscaloosa Lock wall.

Keywords: sonic tests; concrete strength; cracked concrete; pulse velocity; PCA, HEPC & WES soniscopes; pulse velocity; Tuscaloosa Locks.

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54. MITCHELL, L.J. "Dynamic testing of materials". Highway Research Board, NRC, Washington, D.C., Proc., Vol. 33, 1954, pp. 242 - 258.

This paper describes dynamic tests of both sonic velocity and resonant frequency types. Sonic velocity tests were made to evaluate the effect of both air-filled and water-filled cracks on transmittal of signals through concrete.

Keywords: concrete cracks; dynamic testing; pulse velocity; hammer blows; resonant frequency; water-filled cracks.

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55. NATIONAL READY-MIXED CONCRETE ASSOCIATION (NRMCA), "Rebound test for strength of concrete", Techn. Information Letter 86, Oct. 15, 1954.

Test results with the "Swiss test hammer" from two laboratory investigations were discussed. In one case hammer readings were taken on the moulded surface of 6 x 12-in, cylinders immediately after they had been broken in compression. In the other case readings were taken on flexural test beams of 6 x 6-in. square cross section. In both cases results differed by about 1000 psi.

Keywords: compressive strength; impact test; NDT; rebound hammer; Schmidt test hammer; surface hardness.

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56. RILEM (Reunion Internationale des Laboratorie D'Essais et de Recherches sur les Materiaux et les constructions). International Symposium on Non-Destructive Testing of Materials and Structures; Report in 2 Volumes, Paris, France, 1954.

Anisotropy of concrete test specimens, arising from the preparation of concrete, may influence both mechanical and elastic properties and probably the relation between the dynamic properties and compressive strength of concrete. Other variables investigated are the influence of moisture content and the size and shape of test specimens on sonic properties of concrete as well as on hardness and indentation test methods. X-ray and neutron methods as non-destructive test methods are also discussed.

Keywords: NDT; concrete strength; concrete anisotropy; elastic properties; dynamic E modulus; acoustical tests; sonic tests; ultrasonic tests; pulse velocity; vibration tests.

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57. RILEM, Non-Destructive Testing, Paris Symposium 1954, Report. Part A - SONIC TESTS, Papers A-1 to A-32.

Various vibration (sonic) methods used in testing concrete in different countries are described. The advantages and application of each method in general are given and are discussed in the following papers:

1) CABARAT, R.: "Measurement of elastic constants by an acoustical procedure". Paper No. A-1, pp. 9-17.

2) STUTTERHEIM, N., LOCHNER, J.P.A. and BURGER, J.F.: "A method for determining the dynamic Young's modulus of concrete specimens developed for corrosion studies". Paper No. A-2, pp. 18-33.

3) TAKABAYASHI, T.: "Comparison of dynamic Young's modulus and static modulus for concrete". Paper No. A-3, pp. 34-44.

4) KESLER, C.E. and HIGUCHI, Y.: "Problems in the sonic testing of plain concrete". Paper No. A-4, pp. 45-53.

5) ARREDI, F.: "Non-destructive tests on concrete specimens performed in the hydraulic structures laboratory of the Engineering Faculty of Rome". Paper No. A-5.

6) TAKANO, S.: "Determination of concrete strength by a non-destructive method". Paper No. A-7, pp. 62-68.

7) HIGUCHI, Y.: "Studies presented by the author". Paper No. A-8, pp. 69-70.

8) FUJITA, K.I.: "Non-destructive method for concrete". Paper No. A-9, pp. 71-73.

9) BAN, S.: "Activity of the committee on non-destructive concrete inspection of the JSTM". Paper No. A-10, p. 74.

10) KILIAN, G. "Evolution of the mechanical and elastic properties of concretes as a function of age, the proportion of binder and the nature of the aggregates". Paper No. A-11, pp. 75-79.

11) LAZARD: "Report by Lazard". Paper No. A-12, pp. 80-88.

12) DAXELHOFER, J.P.: "Concrete anisotropy brought out by the measurement of the dynamic modulus". Paper No. A-13, pp. 89.

13) DAXELHOFER, J.P.: "Remarks on the use of sonic methods for investigating the liability to frost damage of concretes at the materials testing laboratory of the Lausanne Polytechnical School". Paper No. A-13, pp. 98-105.

14) DAXELHOFER, J.P.: "Note on the static and dynamic moduli of a concrete". Paper No. A-13, pp. 106-107.

15) DAXELHOFER, J.P.: "Note on the variation of the dynamic modulus as a function of the water content of a light-weight concrete". Paper No. A-13, pp. 108.110.

16) ELVERY, R.H.: "Symposium on the non-destructive testing in concrete". Paper No. A-15, pp. 111-119.

17) BEAUZEE, C.: "Errors of measurement in the sonic method". Paper No. A-16, pp. 120-136.

18) JONES, R.: "The testing of concrete by an ultrasonic pulse technique". Paper No. A-17, pp. 137-165.

19) CHEFDEVILLE, J.: "The qualitative control". Paper No. A-19, pp. 166-178.

20) ANDERSEN, J.: "Apparatus for determination of sound velocity in concrete and execution of the measurements". Paper No. A-19A, pp. 179-183.

21) NERENST, P.: "Speed of propagation in concrete determined by a condensing chronograph". Paper No. A-19B, pp. 179-189.

22) NERENST, P.: "Wave velocity as influenced by curing conditions and age". Paper No. A-19C, pp. 200-204.

23) ANDERSEN, J.: "The use of sound-velocity measurements for practical tests of concrete". Paper No. A-19D, pp. 205-208.

24) KAMEDA, Y.: SWAYA, K. and YOKOYAMA, I.: "The non-destructive testing of concrete". Paper No. A-20, pp. 209-215.

25) VOELLMY, A.: "Vibration testing of concrete in structures in Switzerland". Paper No. A-21, pp. 216-218.

26) MAGNEL, G. and HUYGHE, G.: "Determination of the strength of a concrete by a non-destructive process". Paper No. A-22, pp. 219-247.

27) OKUSHIMA, M. and KOSAKA, Y.: Four reports presented. Paper No. A-23, pp. 248-252.

28) BORGES, F.: "Some uses of ultrasounds at the Laboratorio National de Engenharia Eivil". Paper No. A-24, pp. 253-258.

29) MAMILLAN, M.: "The use of sonic methods for the study of freestones". Paper No. A-25, pp. 259-274.

30) DAWANCE, G.: "Application of the vibration test to the study of rocks and rock masses". Paper A-26, p. 275.

31) ANON.: "Non-destructive testing of bituminous concrete. Relationship between the speed of sound propagation and the temperature of the concrete". Paper No. A-27, pp. 277 - 281.

32) MOLES, A.: "A geoseismic apparatus for investigating the compactness of soils". Paper No. A-28, pp. 282-284.

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58. RILEM, Non-Destructive Testing, Paris Symposium 1954. Reports Part B - SURFACE HARDNESS TESTS, Papers B-1 to B-9.

The advantage of rebound and indentation methods of testing concrete is that they require relatively simple and inexpensive apparatus and are easy to perform. There is, however, a wide dispersion of the results which necessitates a large number of measurements. These methods are discussed in the following papers:

1) VASSITCH, P.: "Outline of the various possibilities of non-destructive mechanical tests on concrete - A new proposal by the author". Paper No. B-1, pp. 301-306.
2) GAEDE, R.: "Report on ball test". Paper No. B-2, pp. 307-309.
3) SCHMIDT, E.: "The concrete sclerometer". Paper No. B-3, pp. 310-319.
4) WEIL, G.: "Ball test". Paper No. B-4, pp. 320-321.
5) SA, P.: "Non-destructive testing of concrete". Paper No. B-5, p. 332.
6) VOELLMY, A.: "Examination of concrete by measurement of superficial hardness". Paper No. B-6, pp. 323-336.
7) DAWANCE, G. and JEVTIC, D.: "Use of sclerometer for the determination of the compressive strength of concrete". Paper No. B-7, pp. 337-340.
8) PELTIER, R.: "Test performed on a sclerometer at the Central Laboratory of Ponts et Chaussees in Paris". Paper No. B-8, pp. 341-346.
9) MEYNIER: "Note on the sclerometer used in a laboratory of L'Electricite de France". Paper No. B-9, pp. 347-350.

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59. RILEM, Non-Destructive Testing, Paris Symposium 1954, Reports. Part C - XRAY AND NEUTRON METHODS, Papers C-1 to C-4.

These methods of testing concrete are based on the use of radioactive sources. Application of a gamma-ray absorption test method in concrete with normal thicknesses requires a fairly powerful radioactive source. With such sources suitable precautions must be taken to screen the operator from injurious effects of the radiation, and this may limit the application of the method.

1) BROCARD, J.: "Application of radioisotopes to non-destructive testing of materials". Paper No. C-1, pp. 359-368.
2) JACQUESSON, J.: "Note on the influence of the distance source detector in the use of gamma radiation for measuring densities of soils". Paper No. C-2, pp. 369-374.
3) HUYGHES: "A few measurements results". Paper No. C-4, p. 396.

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60. RINALDI, G. and NEUMAN, G., "Durchleuchtung des Betons zum Studium des Innenaufbaues von Stahlbeton- und Spannbetonstrukturen" (Examination of reinforced and prestressed concrete structures); Beton -und Stahlbetonbau, Vol. 49 (4), April 1954, pp. 88 - 92.

The X-ray pictures show that radiography may be used for examination of some properties of concrete. Location and dimension of reinforcement bars can be determined. Also, deficiencies in concrete placing may be identified and foreign objects located. Effect of external loading on internal deformations and strains in concrete may be observed.

Keywords: NDT of concrete; radioactive methods; radiographical methods; X-ray photography.

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61. ROHNER, F., "Zerstörungsfreie Werkstückprüfung" (Non-destructive testing of materials and parts); Schweizer Archiv für angew. Wissenschaft und Technik, Vol. 20, Nov. 1954, pp. 371 - 373.

Progress in non-destructive testing of materials and parts since 1948 is reviewed under four main headings: radiography, electric-induction tests, magnetic methods and ultrasonic testing. Special attention is paid to radiography with radioactive isotopes.

Keywords: NDT; radiography; electro-inductive tests; magnetic methods; ultrasonic testing; parts testing.

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62. ROSHORE, E.C., "Ultrasonic investigation of cracking in Kansas City flood-wall (Armourdale unit)", Waterways Experiment Station (WES), Vicksburg, Miss., Misc. Paper No. 6-72, May 1954, 44 pp.

During the Kansas river flood of 13 July 1951, the flood-wall was damaged. The extent of wall cracking was determined by means of a soniscope survey of the monoliths in question. The survey involved determination of vertical cracking in 17 monoliths. Description of the soniscope and test procedure is given. The presence of air-filled cracks in concrete lowers the pulse velocity. All portions of concrete monoliths testing less than 16,000 fps were removed. Hair-line cracks less than ½ mm in width are not detected by soniscope.

Keywords: concrete; cracks; hairline cracks; pulse velocity; soniscope; ultrasonic method; NDT.

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63. U.S. ARMY, CORPS OF ENGINEERS, "Field soniscope tests of concrete, 1953 tests". Technical Memorandum No. 6-383, Report No. 1, Waterways Experiment Station, Vicksburg, Miss., Apr. 1954, 18 pp.

These tests were conducted by the concrete research division, ESD. The soniscope used was manufactured in 1951 by McPhar Engineering Co. Toronto, Ont. Test procedure followed the "Proposed tentative method of test", prepared by J.R. Leslie of the HEPC of Ontario in 1952 and published in ASTM Bull. Feb. 1955 (incl. as Appendix in this Report). The following structures were tested in June 1953: 1) Tuscaloosa Lock, 2) Clark Hill Dam, 3) Wolf Creek Dam, 4) Bull Shoals Dam, 5) Norfolk Dam and 6) PCA Farm concrete expt. site, Perry. Ga.

Keywords: concrete; deterioration; cracking; pulse velocity; quality of concrete; soniscope; ultrasonic tests.

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64. WHITEHURST, E.A., "Pulse-velocity techniques and equipment for testing concrete". Highway Research board, NRC, Washington, DCC., Proc. Vol. 33, 1954, pp. 226 - 242. (Tennesee Highway Research program).

Author describes development of pulse-velocity technique and equipment from its early beginning until 1959. The pulse-velocity measuring devices to date fall into three classes: 1) Single physical impact (hammer-blow); no visual observation of test signals. 2) electronic devices with pulse being generated electronically; signals are displayed on a cathode ray oscilloscope. 3) Pulse by a physical blow from a motor-driven hammer; signals are portrayed on an oscilloscope.

Keywords: electronic interval timer; microtimer; phonograph pick-ups; soniscope; transducers; thyratron; pulse velocity; ultrasonic concrete tester.

1955

65. BREUNING, S.M. and ROGGEVEEN, V.J., "Fundamentals of field soniscope testing". Hwy. Res. Board Proceedings, Vol. 34, 1955, pp. 379 - 386. (Joint Hwy. Res. Project with MIT).

This paper describes some aspects of the use of the soniscope for field testing of concrete. The significance of sound velocities in various materials are discussed. Special test patterns and layouts for applying the transducers will often facilitate data interpretation. Practical problems of soniscope field testing are described, including procedures used and difficulties encountered. Inaccuracies introduced by components of this complex electronic instrument are also discussed.

Keywords: concrete; NDT method; pulse velocity; transducers; soniscope; field testing.

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66. BELAGUER de PALLEJA, J.M., "Ensayo del hormigon puesto en obra" (Testing concrete in existing structures), Cemento - Hormigon (Barcelona), Vol. 23, No. 253, April 1955, pp. 146 - 149.

To estimate concrete compressive strength of existing structures, non-destructive test methods have been applied widely. One type of such ND tests are surface hardness tests, which results may be correlated with compr. strength of concrete. One instrument accepted as a most practical tool is a rebound hammer - sclerometer, which really is the same as a Schmidt test hammer.

Strength calibration curves have to be prepared for different angles of direction used.

Keywords: NDT of concrete; surface hardness tests; calibration curves; rebound readings; Schmidt test hammer.

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67. DAWANCE, G. and CHEFDEVILLE, J. "Schallmessungen an Beton. Neue Methoden für die Ermittlung der Qualität von Beton durch laufzeitmessungen des Schalls" (Acoustic measurements on concrete. New methods for determining quality of concrete), Schweizer Archiv, Vol. 2., 1955, pp. 223 - 234; 313 - 325. (in French).

De nets progres ont ete realises ces dernieres annees au de l'examen qualitatif du beton au moyen d'ondes sonores. De ce fait, it s'averait absolument necessaire de faire le dans l'etat actuel de ces recherches. Il y avait donc lieu de fournir totes les explications utiles concernant l'ensemble des relations fondamentales fixant le probleme des measures sonores et purvant etre exprimees a formules auxquelles interviennent encore les grandes physiques concomittantes.

Keywords: acoustic measurements; sonic waves in concrete; resonant frequency; pulse velocity; vibrations caused in concrete.

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68. DIN Entwurf, "Kugelschlagprüfung von Gas- und Schaumbeton - Richtlinien für die Anwendung" (Ball-impact test of aerated and foamed concrete - Guidelines for use), Draft proposal June 1955. Betonstein - Zeitung, Vol. 21 (10), 1955. pp. 476 - 478; also: Beton und Stahlbetonbau, Vol. 50 (8), Aug. 1955, pp. 224 - 225.

This proposal was prepared by Dr. K. Gaede, Hannover, adapting a similar test specified by DIN 4240 (1954) for the ball-impact test of dense concrete. The use of a spring-operated or pendulum-operated hammer for the non-destructive determination of the strength of aerated and foamed concrete is dealt with, and a relevant draft Standard Specification serving as a set of rules for the application of this method is submitted for discussion.

Keywords: NDT; ball indentation; concrete hardness; Einbeck pendulum hammer; Frank spring hammer.

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69. ELVERY, R.H. and VALE, D.W. "A portable ultrasonic concrete-testing apparatus", Magazine of Concrete Research, Vol. 7, No. 21, Nov. 1955, 161 pp.

Built at Univ. College, London, in two separate units for easy portability, this apparatus is convenient for field testing work. It is basically similar to the Road Research Lab. ultrasonic equipment, but about half its weight. Some new features have been incorporated, providing greater convenience in use and servicing.

Keywords: concrete testing non-destructively; ultra-sonic testing; pulse velocity; ultrasonic equipment.

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70. HYDRO-ELECTRIC POWER COMMIS. OF ONTARIO, Research Division, "New technique for soniscope inspection", Ontario Hydro Research News, Vol. 7, April/June, 1955, pp. 19 - 21.

To overcome range limit for soniscope use, holes were drilled vertically and, by using special transducers, dams with bases exceeding 150 ft were inspected. Concrete thickness range for soniscope is limited to 50 to 60 ft. The effective range has been increased by the new technique by using drill holes in 40-ft

sections. In future designs of concrete dams, holes could be cast during construction, rather than be obtained by drilling.

Keywords: concrete crack detection; drill-hole transducers; pulse velocity; range limit for soniscope; soniscope; transducers; wave velocity.

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71. JONES, R., "A vibration method for measuring the thickness of concrete road slabs in situ", Magazine of Concrete Research, Vol. 7, No. 20, July 1955, pp. 97 - 105.

The velocity of propagation of vibrations at audio and ultrasonic frequencies are measured at the surface of concrete slab. From the results and theoretical analysis a graph is prepared, which enables calculating the thickness of the slab. Slab thicknesses varied from 4 to 9 in. with the results been satisfactory to within 10 per cent.

Keywords: dynamic testing; pulse velocity; measuring thickness of concrete slab; sonic test; ultrasonic frequencies; surface waves; wave length.

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72. KOZAN, C.P., "Nondestructive testing of concrete pavements", Proceedings, Highway Research Board, Vol 34, 1955, pp. 368 - 378.

An investigation was conducted (at Waterways Experiment Station, Vicksburg, Miss.) to determine the suitability of an electronic interval timer for use as an expedient nondestructive means of flexural strength determination. Longitudinal wave velocities through concrete test beams and a slab in-situ were determ. with a interval timer, and flexural strength were predicted by formulas and the results were compared with flexural strength of beams cut

from the slab. It was concluded that the electronic interval timer is capable of providing results of practical utility for pavement evaluation. The accuracy of flexural strength determination is well within the accuracy of a suggested correlation between dynamic E and flexural strength.

Keywords: concrete flexural strength; electronic interval timer; dynamic modulus E; longitudinal wave velocity; NDT method.

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73. LESLIE, J.R., "Proposed tentative method of test for the measurements of the pulse velocity of propagation of elastic waves in concrete", ASTM Bulletin, Feb. 1955, pp. 19 - 22.

At the request of Subcomm. II-e of ASTM Committee C-9, in 1952 J.R. Leslie prepared this proposal and also submitted a memorandum concerning the theory of propagation of elastic waves in concrete. This proposal served as a basis for the "Tentative Method of Test for Pulse Velocity Through Concrete", which first appeared in 1967 Book of ASTM Standards, Part 10, as C 597-67T. In 1968, the C 597-68T appeared in Part 10 of 1968 Book of ASTM Standards, as revised by C-9 Sub. II-e. In 1971 it was adopted as standard C 597-71 by the ASTM.

Keywords: concrete; cracks; determination; elastic waves; pulse velocity; travel time; sonic vibrations; soniscope; ultrasonic method.

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74. PHILLEO, R.E., "Comparison of results of three methods for determining Young's modulus of elasticity of concrete", ACI Proceedings, Vol. 51, No. 5, Jan. 1955, pp. 461 - 472.

The elastic response of concrete to static, resonance and pulse velocity tests is discussed. Because of wide variations in static

testing techniques and the heterogeneity of concrete, the results of Young's modulus calculated from the three methods do not necessarily agree. The pulse velocity has advantages in that testing is not confined to regularly-shaped laboratory specimens; however, it is so affected by the heterogeneity of concrete that calculations of Young's modulus are discouraged.

Keywords: dynamic test methods; nondestructive testing; modulus of elasticity of concrete; pulse velocity; resonant frequency; sonic tests; Young's modulus of elasticity of concrete.

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75. PETERSEN, P. and STOLL, U.W., "Relation of rebound-hammer test results to sonic modulus and compressive strength data", HRB Proceedings, Vol. 34, 1955, pp. 387 - 399.

Relationships exist between the amount of rebound on concrete of a light steel hammer and other particular properties of the concrete, such as compr. and flexural strength and sonic modulus of elasticity. Under controlled laboratory conditions there appeared to be a pronounced degree of correlation between hammer reading and compressive strength of concrete. Sonic modulus of E was obtained on each cylinder by vibrating the specimen in flexure.

Keywords: concrete strength; modulus of E; rebound hammer; sonic modulus; NDT methods.

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76. WHITEHURST, E.A. and PARKER, W.E., "Dynamic Tests", ASTM Special Technical Publication No. 169, 1955, pp. 104 - 114.

Dynamic tests in use may be subdivided into three groups:

1) Sonic tests, involving the resonant frequency of a test specimen;

2) Pulse velocity tests, measuring the velocity of compressional pulse travelling through concrete;
3) Rebound hammer readings or diameter of indentation caused by the hammer blow.

Description of each method and interpretation of the results obtained are given in detail.

Keywords: dynamic tests; nondestructive testing; pulse velocity; modulus of elasticity; resonant frequency; sonic test; ultrasonic tests.

1956

77. CHANG, T.S. and KESLER, C.E., "Correlation for sonic properties of concretes with creep and relaxation", ASTM Proceedings, Vol. 56, 1956, pp. 1257 - 1272.

This paper presents a method of relating the properties of concrete that can be obtained from sonic testing to the creep behaviour in compression and flexure, and relaxation behaviour in compression. The results presented provide a means of predicting creep and relaxation behaviour of concrete from a relatively simple sonic test.

Keywords: concrete; compressive strength; creep in compression and tension; flexural strength; dynamic properties; relaxation; sonic tests.

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78. GAEDE, K., "Kugelschlagprüfung von Beton; Einfluss des Prüfalters" (Ball-impact test of concrete; effect of test age), Beton -und Stahlbetonbau, Vol. 51 (8), Aug. 1956, 190 pp.

Concrete (cube) compressive strength calculation from indentation measurements refers to the 28-d. tests. If concrete age is different, the results have to be corrected for the n- day age by using a factor shown in a table for the spring hammer-produced indentation. This factor for ages from 10 to 3000 days varies from 1.55 to 0.63, the 28-d age being 1.00.

Keywords: concrete hardness; concrete strength; effect of age; ball indentation; age correction factor; pendulum hammer; spring test hammer.

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79. LAMB, D.R., "A new soniscope - the elastiscope". The Highway Research Board, Proceedings, Vol. 35, 1956, pp. 418 - 423.

Recent developments in the sonic methods of testing allow the approximate estimation of strength without damaging concrete. A new type of soniscope has been developed at the University of Wyoming. The fundamental natural frequency of the specimen is determined by vibration at different frequencies by a driver actuated by a variable frequency oscillator. The frequency which causes the greatest meter indication of a pick-up is the natural frequency of the specimen. The sonic modulus of elasticity is calculated as $E=CWn^2$. The method is given in the ASTM Standard C 215 52T.

Keywords: concrete quality; non-destructive testing; soniscope; sonic modulus of E.

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80. THE ULTRASONIC TESTING OF CONCRETE. Report of a meeting held at University College, London, England. Magazine of Concrete Research, Vol. 8, No. 24, Nov. 1956, pp. 105 - 106.

A meeting called by Dr. R. Jones of the Road Research laboratory was held at the Dept. of Civil and Municipal Engineering, University College, to exchange information on the technique, and to discuss in detail factors affecting the apparatus used. A summary of the main conclusion is given. It was emphasized that the method is essentially one of comparison and, both in structures and laboratory, velocity measurements can reliably check variation of concrete quality.

Keywords: NDT; apparatus for ultrasonic testing; coupling; transducers; effect of age; curing; density; pulse velocity.

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81. VERBECK, G., "Non-destructive tests for deterioration of concrete specimens subjected to frost action", PCA, Research Dept. Bulletin 79, Dec. 1956 (reprinted from Transactions, Fifth Congress on Large Dams, Paris, 1955).

This paper discusses advantages and disadvantages of several methods of measuring deterioration of concrete specimens in freezing and thawing tests. These methods include visual examination, measurements of weight change, length change, resonant frequency and pulse velocity.

Keywords: concrete deterioration; freezing-thawing tests; length change; pulse velocity; resonant frequency; modulus of elasticity; weight loss.

1957

82. GAEDE, K., "Kugelschlagprüfung von Beton mit dichtem Gefuge. Einfluss des Prüfalters" (Ball-impact test of dense concrete. Effect of age of concrete), Deutscher Ausschuss für Stahlbeton, Heft 128, 1957, 17 pp.

The guidelines for concrete hardness tests by using steel ball impact indentation measurements are given in DIN 4240 (1954). compressive strength values are obtained from the 28-d test cubes. For other ages relationships change. In order to establish corresponding values, test series were carried out at Hannover Techn. High School with concrete test specimens ranging in age from 7 to 720 days. Correction factors are calculated for different ages of concrete.

Keywords: NDT; concrete hardness; strength; ball indentation; age correction factor; pendulum hammer.

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83. JONES, R., "The effect of frequency on the dynamic modulus and damping coefficient of concrete", Magazine of Concrete Research, Vol. 19, No. 26, 1967.

Resonant frequency determination of concrete beams in flexural, longitudinal and torsional modes of vibration to study the effect of frequency on the dynamic Young's modulus and dynamic shear modulus. For wet concrete no difference seen in Young's modulus from the flexural and longitudinal vibrations. For dry concrete Young's modulus from flexural vibrations was lower than from longitudinal vibrations. Smaller beams tend to give a higher Y-modulus than do larger beams of the same concrete.

Keywords: damping coeff. of concrete; dynamic properties; elastic properties; modulus of elasticity; shear modulus; flexural and longitudinal vibrations.

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84. KLIEGER, P., "Long-time study of cement performance in concrete. Chapter 10; Progress report on strength and elastic properties of concrete". Journal ACI, Proceed. Vol. 54, Dec. 1957, pp. 481 - 504.

This report presents strength data through three years for concrete specimens used in the study. It also presents information on the elastic properties of the concretes as determined by both static and dynamic means, and pulse velocities as determined by the soniscope.

Keywords: dynamic tests; elastic properties; pulse velocity; resonant frequency; modulus of elasticity; sonic tests; soniscope; ultrasonic testing.

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85. KESLER, C.E. and CHANG, T.S., "A review of sonic methods for the determination of mechanical properties of solid materials", ASTM Bulletin No. 225, Oct. 1957, pp. 40 - 46.

Sonic testing methods have a major advantage over most static methods. They are non-destructive, and consequently may be used for inspection of finished preducts. Several sonic testing methods have been developed. These methods are reviewed as follows: A. Resonant frequency type - 1) Continuous vibration at constant amplitude, and 2) Decaying amplitude. B. Wave velocity type - 1) Pulse velocity: (a) Soniscope, (b) Interval timer, and 2) Standing wave velocity.

Keywords: resonant frequency; continuous vibration; constant amplitude; decaying amplitude; pulse velocity; wave velocity; soniscope; interval timer; dynamic modulus of E; NDT methods.

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86. ZOLDNERS, N.G., "Calibration and use of impact test hammer", ACI Journal Proc., Vol. 54, No. 2, Aug. 1957, pp. 161 - 165.

Empirical relationship is developed graphically between cylinder compressive strength of concrete and the rebound number of the Schmidt impact test hammer when a steel plunger is impinged against the side surface of test cylinder under controlled conditions. Calibration charts for 2 Schmidt test hammers, type CT-320, for concrete made with crushed limestone and natural sand aggregates are compared with the manufacturer's calibration curve. Test hammer has to be calibrated for use on concrete made with aggregates produced from a specific source. Correction of readings has to be made for impact direction and also for moisture condition of the concrete surface.

Keywords: compressive strength; surface hardness; impact test; rebound hammer; Schmidt test hammer; calibration curve.

1958

87. CAWKELL, A.E., "The investigation of the quality of thick concrete by ultrasonic pulse propagation", Magazine of Concrete Research, Vol. 10, No. 28, March 1958, pp. 23 - 26.

The velocity of ultrasonic pulses through concrete is measured by an oscillograph timing technique. There is a relation between pulse velocity and concrete quality. To increase the range by about 8 ft through good quality concrete with the standard instrument Type UCT, higher power and low frequency sharply directional magnetostriction transducers were used. It is considered that 20 ft is the maximum length possible.

Keywords: concrete quality; modulus of E; pulse velocity; soniscope; transducers; NDT method.

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88. KAPLAN, M.F., "Compressive strength and ultrasonic pulse velocity relationship for concrete in columns", ACI Journal Proc., Vol. 54, No. B, Fe. 1958, pp. 675 - 688.

Concrete strength variability in columns as indicated by test cubes and by pulse velocity measurements in columns was investigated. Pulse velocity values for the concrete in the columns gave a better indication of the variation in strength quality of concrete than did compressive strength results on concrete test cubes.

Keywords: concrete; compressive strength; pulse velocity; ultrasonic testing; NDT methods.

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89. KOLEK, J., "An appreciation of the Schmidt rebound hammer". Magazine of Concrete Research, Vol. 10, No. 28, March 1958, pp. 27 - 36.

The Schmidt rebound test hammer is described and some theoretical aspects about the functioning of the hammer are discussed. The method of performing the test and its limitations under different conditions are described.

Keywords: concrete; compressive strength; dynamic test methods; surface hardness; rebound reading; NDT methods.

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90. NON-DESTRUCTIVE TESTING OF CONCRETE (Editorial), The Indian Concrete Journal, Vol. 32, No. 2, Be. 1958, pp. 35 - 36.

Describes research work on non-destructive testing of concrete done at the Indian Institute of Technology, Kharagpur, correlating the wave velocity of an ultrasonic pulse with the strength of concrete. To measure the velocity of pulses through concrete, three main classes of devices have been used: 1) single-blow devices; 2) ultrasonic devices and 3) repetitive-blow devices.

Keywords: dynamic testing; pulse velocity; resonant frequency; ultrasonic testing; NDT methods.

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91. RILEM: "Analyses of the RILEM questionnaire on non-destructive testing of concrete", RILEM Techn. Committee on NDT of concrete, Chairman's report, RILEM Bulletin No. 41, 1958.

At the working group of RILEM Techn. Committee on NDT main answers to the questionnaire were discussed in detail and summarized in a table where it shows clearly where there is a divergence of opinion between users. All together, eight NDT methods were discussed as follows: (A) Sonic method; (B) Ultrasonic m.; (C) Hammer pulse method with interval timer; (D) Hammer pulse method with oscillogr.; (E) Sustained vibrations; (F & G) Indentation or sclerometer method; (H & J) Gamma-ray and Neutron method. A total of 122 answers were received from 20 countries.

Keywords: gamma rays; hammer pulse; indentation test; neutron methods; rebound hammer; sclerometer; ultrasonic method.

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92. STURRUP, V.R. "Evaluation of pulse velocity tests, made by Ontario Hydro", Proceedings, 37th Annual Meeting, Highway Research Board, Washington, D.C., Jan. 6 - 10, 1958.

The soniscope was developed at the Ontario Hydro Research Division as a NDT method for following the cracking behaviour in concrete gravity dams by pulse velocity techniques. Internal cracks are detected by an abnormal increase in transmission time and/or reduction in pulse amplitude. The soniscope has been used to some extent to follow strength development of concrete at early ages. No well defined correlation has been established between pulse velocity and 28-day compr. strength of concrete.

Keywords: NDT; concrete compressive strength; cracking of concrete; pulse velocity.

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93. VARGHESE, P.C., "Testing concrete by ultrasonic pulse", The Indian Concrete Journal, Vol. 32, No. 2, Feb. 1958, 46 pp.

In this paper results are presented of an investigation undertaken by the Civil Engineering Dept. Of the Indian Institute of Technology, Kharagpur, on the use of the ultrasonic pulse velocity method in predicting the strength of concrete test specimens.

Keywords: non-destructive testing; compressive strength of concrete; dynamic test methods; pulse velocity; resonant frequency; ultrasonic testing.

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94. WALTER, L., "Progress in non-destructive testing of concrete", Indian Concrete Journal, Vol. 32, No. 2, Feb. 1958, pp. 50-52.

This article describes the use of ultrasonics for 1) quality control and measurements of compressive strength during manufacture of precast concrete units; 2) flaw detection; 3) crack detection.

Keywords: concrete compressive strength, crack detection; dynamic test methods; modulus of elasticity; non-destructive testing; pulse velocity; resonant frequency, sonic tests; ultrasonic tests.

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95. WILLETTE, C.H., "Investigation of the Schmidt concrete test hammer", U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., Misc. Paper No. 6 - 267, June 1958, 11 pp.

Tests were made to evaluate the readings (indicating quality and strength) obtained with the Schmidt hammer on hardened concrete surfaces by correlating them with results obtained by conventional test methods. The investigation indicated that the Schmidt hammer can be used to estimate the strength of concrete provided it is calibrated under the conditions for which it is to be used, and the curves or data developed are used instead of the manufacturer's graphs.

Keywords: concrete; compressive strength; hardness; calibration curve; effect of surface moisture; test direction; aggregate type; rebound readings; Schmidt rebound test hammer.

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96. ZHUKOV, V.S., KRYLOV, N.A. and SUDAKOV, V.V., "The use of radioactive isotopes for the quality control of concrete and other building materials". Doklady Mezhvuzovsoi Konferentsii po Ispytaniyam Sooruzhenii, Leningrad, USSR, 1958, Proceedings pp. 205 - 214. (in Russian). (Nat. Lending Library for Science & Technology, D.S.I.R. RTS 2166, Boston SPA, Yorkshire, G.B., Oct. 1962).

The use of gamma rays for assessment of properties of materials is based on the reduction in their intensity following their interaction with the given media. The radiometric method makes it possible to control the density of the material, its composition,

moisture content, compaction of fresh concrete, control of cement setting process and the strength of concrete.

Keywords: bulk density; cement setting; compaction; concrete; homogeneity; gamma rays; isotopes; radiometric method.

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97. YAKHONTOV, Yu.K., "Determination of the density of concrete by means of gamma radiations". Doklady Mezhvuzovskio Konferentii po Ispytaniyam Sooruzhenii, Leningrad, USSR, 1958; Proceedings, pp. 255 - 261 (in Russian). (Nat. Lending Library for Science & Technology, D.S.I.R. RTS 2166, Boston SPA, Yorkshire, G.B., Oct. 1962).

The specimens had constant cross-sectional dimensions of 12 x 10 cm and different thicknesses in the direction of irradiation. The radiation sources used were Co^{60} with a radiation energy of 1.35 Mev, and the isotope Ca^{137} with a radiation energy of 0.661 Mev. currently, gamma radiation is used for determining the density of fresh concrete with isotope and counter fully embedded in the concrete mixture.

Keywords: concrete; density; gamma rays; isotopes; radiometric method.

1959

98. Highway Research Board, "Effects of Concrete Characteristics on the Pulse Velocity", HRB Bulletin No. 206, a Symposium published in 1959, Washington, D.C. (continued in No. 99E).

This symposium has been held to review the use of soniscope for measuring the pulse velocity in concrete, during the last ten years. The greatest value of the soniscope is in the evaluation of

uniformity of concrete structures. Other information of great value is the determination of the trend in the performance of concrete over a period of exposure time in field. A third use of the soniscope is the determination of a general level of concrete quality, or its strength. Observation of crack development in concrete structure might also be considered as routine use of pulse velocity, ultrasonic pulse velocity and sonic tests.

Keywords: concrete symposion; pulse velocity testing; quality control; cracks.

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99. Highway Research board, Bulletin No. 206 (cont'd from No. 98). Papers presented at the Symposium of the 37th Annual Meeting of the HRB, Jan. 6 - 10, 1958, held in Washington, D.C.

1) STURRUP, V.R., "Evaluation of pulse velocity tests by Ontario Hydro". HRB Bull. No. 206, 1959, pp. 42- 45.
2) WOODS, K.B. and McLAUGHLIN, J. F., "Application of pulse velocity tests to several laboratory studies of materials", pp. 16 - 27.
3) TREMPER, B., "Evaluation of pulse velocity tests", p. 28.
4) MEYER, R.C., "Eight years of pulse velocity tests on concrete pavements in Kansas", pp. 31 - 36.
5) BULLOCK, R.E. and WHITEHURSE, E.A., "Effect of certain variables on pulse velocities through concrete", p. 37.
6) MATHER, Bryant, et al, "Use of the soniscope by Concrete Division, U.S. Army Waterways Expt. Station", pp. 42 - 45.
7) LAVERTY, B.R. and SPENCER, R.W., "Appraising the quality and performance of concrete by pulse velocity measurements", pp. 46 - 56.
8) WHITEHURST, E.A., "Effect of variations in mix design or curing conditions on a pulse velocity-strength relationship", pp. 57 - 63.

9) OLESON, C.C., "Evaluation of pulse velocity tests made with Portland Cement Association soniscope", p. 64.

10) BAWA, K.S., "General discussion of the symposium", p. 70.

11) WHITEHURST, E.A., OLESON, C.C. and Valore, R.C. Jr., "Symposium summary", pp. 72 - 74.

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100. FORRESTER, J.A., "The use of gamma radiography to detect faults in grouting", Magazine of Concrete Research (London), Vol. 11, No. 32, 1959, pp. 93 - 96.

Ultrasonic pulse technique, utilized to check if a grouting duct is completely filled to prevent corrosion of prestressing steel and ensure complete bond between the steel and concrete, has a limited sensitivity. The use of gamma radiography has obvious advantages but the image must be clear enough for defects to be visible.

Keywords: bond (between steel cable and concrete); corrosion of prestressing cables; defects (voids) in concrete grouting of cables; gamma radiography; ultrasonic pulse technique.

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101. KAPLAN, M.F., "The effect of age and water/cement ratio upon the relation between ultrasonic pulse velocity and compressive strength of concrete", Magazine of Concrete Research (London), Vol. 11, No. 32, July 1959, pp. 85 - 92.

It was found that ratio of changes in pulse velocity and compressive strength due to changes in water/cement ratio is not generally the same as that due to a change in age.

Keywords: age of concrete; aggregate/cement ratio; compressive strength; ultrasonic pulse velocity.

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102. PANIAN, F.C. and VAN VALDENBURG, H.E., "Development of ASTM standard reference blocks for ultrasonic inspection". ASTM Proceedings, Vol. 59, 1959, pp. 1237 - 1260.

A review of the investigation, developing ASTM aluminum alloy ultrasonic standard reference blocks as described in E 127-58T. Variables affecting the ultrasonic response from the hole in the block are discussed. Control of parameters and techniques of the ultrasonic tests used to evaluate the stock and finished reference blocks.

Keywords: aluminum alloy blocks; reference blocks; ultrasonic standards; ultrasonic inspection.

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103. URZHUMTSEV, Yu.S., "The non-destructive determination of concrete strength by means of the dynamic modulus of elasticity and the damping constant of sound". Sbornik statey IC, izsledovaniya po betonu i zhelezobetonu; Izdatelstvo Akademii Nauk Latviiskio SSR, Institut stroitelstva i architekturi, Riga, 1959, pp. 5 - 31 (in Russian), 54 refs.

Based on the analysis of the rheological model of concrete, a theoretical relationship is established between strength of concrete and its elastic and inelastic properties, which is determined by use of ultrasonic pulse equipment.

Keywords: NDT; dynamic testing; mod. of elasticity E; elastic properties; plasticity; pulse velocity; ultrasonic tests.

1960

104. ASTM, "Standard Test Method for Fundamental Transverse, Longitudinal and Torsional Frequencies of Concrete Specimens", 1960 ASTM Book of Standards, Part 4, Designation ANSI/ASTM C 215 - 60. (ASTM C 215 - 55T).

This method covers measurement of fundamental transverse, longitudinal and torsional frequencies of concrete prisms and cylinders for the purpose of calculating dynamic Young's modulus of elasticity, the dynamic modulus of rigidity and dynamic Poisson's ratic. The method is intended primarily for detecting significant changes in the dynamic E of laboratory or field test specimens that are exposed to deteriorating influences. It may be used to assess the uniformity of concrete, but should not be considered as an index of compressive or flexural strength.

Keywords: concrete; dynamic modulus of E; dynam. mod. of rigidity; dynam. Poisson's ratio; fundamental frequency; Young's modulus of elasticity; quality of concrete specimens.

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105. KAPLAN, M.F., Effect of incomplete consolidation on compressive strength and flexural strength, ultrasonic pulse velocity, and dynamic modulus of elasticity of concrete", ACI Journal Proceedings, Vol. 56, March 1960, pp. 853 - 868.

Concrete mixes were used to make 20-in. beams and 6-in. cubes for UPV, resonant frequency, flexural and compressive strength tests at 7,28 and 91 days age. The amount of consolidation was varied by vibrating the concrete for different lengths of time. The maximum void content was 32 percent.

Keywords: compressive strength of concrete; consolidation by vibration in moulds; flexural strength, ultrasonic pulse velocity; void content.

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106. KAPLAN, M.F., "The relation between ultrasonic pulse velocity and the compressive strength of concrete having the same workability but different mix proportions", Magazine of Concrete Research (London), Vol. 12, No. 34, 1960, pp. 3 - 8.

It is concluded that, for concretes made of the same type of material, curves relating pulse velocity to compressive strength may be drawn for concrete of the same workability but different mix proportions, provided that the tests are done at the same age.

Keywords: age of concrete; aggregate/cement ratio; compressive strength; ultrasonic pulse velocity; water/cement ratio; workability.

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107. LSSR (Latvian Soviet Republic), "Investigation methods on physical-mechanical properties of materials" (Series of four articles); Sbornik statey V, izsledovaniya po betonu i zhelezobetonu. Izdattelstvo Akademii Nauk Latviskoi SSR. Institut stroitelstva i architekture, Riga, 1960, pp. 109 - 170 (in Russian).

Research methods:

1) URZHUMTSEV, Yu, S., "Investigating autoclaved silicate concretes by ultrasonic method", pp. 109 - 118.
2) SINCIS, I.A., "Ultrasonic apparatus to determine the pulse travel time and damping constant of concrete", pp. 119 - 126.
3) URZHUMTSEV, Yu. S., "Influence of water saturation of concrete on its sound damping constant, coeff. of structural non-uniformity and dynamic modulus of elasticity", pp. 126 - 138.

4) DSENIS, V.V., "Investigating cement paste hardening by acoustic impulse method", pp. 126 - 138.

Keywords: atomic methods, cement and concrete research; chemically bound water; hydrated cement paste; nuclear magnetic resonance; water classes in concrete.

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108. SELIGMANN, P., "Possible applications of nuclear magnetic resonance in cement and concrete research", Journal of the Research and Development Laboratories, PCA, Vol. 2, No. 3, Sept. 1960.

The principles of the recently developed nuclear magnetic resonance techniques are described. Their potential application in cement and concrete research, particularly in studies of the classes of water present in the hydrated cement paste are examined.

Keywords: atomic methods, cement and concrete research; chemically bound water; hydrated cement paste; muclear magnetic resonance; water classes in concrete.

1961

109. CATHARIN, P., (Research Inst. of Austrian Cement Plant Assoc., Wien), "The non-destructive testing of standard prisms for determining the compressive strength", Zement- Kalk- Gips, No. 9, 1961, pp. 370 - 384 (in German), 50 ref.

By using appropriate formulae it is possible to calculate the compr. strength of concrete from the measured value of the modulus of elasticity E and the shear modulus G. The EG/D ratio is found to be dependent on the rate of hardening. Graphical relations

between E,G and compr. strength can be established by a curve for each measurement series.

Keywords: NDT; modulus of elasticity; shear modulus; concrete compr. strength; correlation curve; effect of moisture; hydration degree effect.

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110. FACAOARU, I., "Contribution a l'etude de la relation entre la résistance de beton a la compression et la vitesse de propagation longitudinale des ultra-sons", RILEM Bulletin, Matériaux et constructions essais et recherches, No. 12, Sept. 1961, Paris, pp. 125 - 154.

The author has studied the influence of the following parameters on the relation between the compressive strength of concrete and the speed of propagation of ultra-sounds; the W/C ratio; the batching of cement; the grain size; the nature of cement; the time of vibration; the nature of the granular material; and curing temperature. The relation obtained, which is of the exponential type, is independent of the W/C ratio or the nature of cement, within a certain limit of fineness. On the other hand, it depends on the other factors, expressed by different curves.

Keywords: compressive strength of concrete; ultrasonic pulse velocity; W/C ratio; fineness of cement; nature of cement.

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111. LSSR (Latvian Soviet Republic), "Acoustical concrete quality testing" (series of five articles); Sbornik statey VI, izsledovaniya po betonu i zhelezobetonu, Izdatelstvo Akademii Nauk Latviyskoi SSR, Institut stroitelatva i architekturi, Riga, 1961, pp. 209 - 261 (in Russian).

Research method:

1) LATISHENKO, V.A. and URZHUMTSEV, Yu. S., "Principal basis for establishing GOST standards on use of acoustic methods for determination of concrete physical-mechanical properties", pp. 200 - 214.
2) URZHUMTSEV, Yu. S. and LATISHENKO, V.A., "Precision and limitations in the use of acoustic test methods for concrete", pp. 215 - 229.
3) BALOSIS, A.A. and SPINCIS, I.A., "Apparatus for determining elastic and in elastic characteristics of building materials by acoustic methods", pp. 231 - 240.
4) DSENIS, V.V. and SPINCIS, I.A., "Investigating relationship between the sound damping constant and hardening of cement paste", pp. 241 - 248.
5) CHUDARS, Y.E., MAKSIMOV, R.D. and SKVORCOV, N.I., "Comparison of moisture control in building materials by the method of neutron radiation and by neutron backscatter method", pp. 249 - 261.

Keywords: acoustic concrete testing; concrete elastic and in elastic properties; hardening of cement paste; damping content; moisture determination; neutron radiation; neutron backscatter.

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112. PANIAN, F.C. and VAN VALDENBURG, H.E., "Development of ASTM standard reference blocks for ultrasonic inspection", Non-destructive Testing, Jan./Feb., 1961, pp. 45 - 57.

A review is given of the investigation which led to the development of the ASTM aluminum alloy ultrasonic standard reference blocks, described in the "Recommended Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks" (E 127-58T). The physical variables affecting the ultrasonic response from the hole or artificial discontinuity in the blocks are discussed.

Keywords: aluminum alloy reference blocks; ultrasonic standard reference clocks; step blocks; test hole.

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113. SHILSTONE, C.M. and SHILSTONE, J.M., "Ultrasonic inspection of hardened concrete", Nondestructive Testing, Vol. 19, No. 1, Jan./Feb. 1961.

Ultrasonic inspection of hardened concrete is a relatively new technique. Equipment and procedures are similar to that used for inspection of metals, except that input frequency is relatively low. There is need to know the concrete mix to be tested. Mix variables materially affect the longitudinal wave velocity.

Keywords: concrete; wave velocity; vibration; NDT method; ultrasonic pulse.

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114. SPINNERS, S. and TEFFT, W.E., "A method for determining mechanical resonance frequencies and for calculating elastic moduli from these frequencies", ASTM Proceedings, Vol. 61, 1961, pp. 1221 - 1238.

Techniques for exciting, detecting and measuring the mechanical resonance frequencies of solid specimens are described in Part I. In addition, relations are given in Part II for computing the appropriate elastic moduli from these resonance frequencies. The method described is often referred to as "sonic" because the resonant frequencies involved are usually in the sonic range (up to about 20 kc). However, it is believed that the term "resonance method" is more accurate because it is more descriptive of the method.

Keywords: elastic moduli; resonant frequency; dynamic resonance measurements; vibrations.

1962

115. DEUTSCHE NORMEN - DIN (German Standards), "Kugelschlagprüfung von Beton mit dichtem Gefüge - Richtlinien für die Anwendung", DIN 4240, April 1962 (Ball impact testing on hardened concrete surface - Guidelines for its use). This is a completely revised DIN 4240, Sept. 1954 issue.

This test method is based upon the Brinell indentation principle in testing metals. It consists essentially of hitting the surface of concrete in a standard manner and measuring the size of the indentation. A spring-activated weight hits a steel hammer housed in a tubular frame, with the tip of hammer fitted with different diameters of balls. The diameter of it is measured and correlated with the compressive strength of concrete.

Keywords: concrete strength; concrete surface; indentation; impact; spring mechanism; steel ball; test hammer.

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116. FILONIDOV, A.M., "Experience in using the ultrasonic method for evaluating concrete quality in structures", Beton i Zhelezobeton, Gosstrollzdat, Moscow, No. 6, 1962, pp. 259 - 262 (in Russian).

To evaluate strength of concrete beams and slabs subjected to heavy loads, two criteria should be used:

1) Compr. strength of concrete determined by ultrasonic pulse velocity measurements should meet design strength requirements.

2) The quality of concrete structure should be evaluated by comparing compr. strength determined by ultrasonic pulse velocity with crushing compressive strength of test specimens.

Keywords: NDT; compr. strength; concrete quality in structure; pulse velocity measurements.

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117. JONES, R., "Non-destructive testing of concrete", Cambridge University Press, 1962. 87 pp. book.

No direct measurement of the strength properties of concrete is possible without destructive tests. It is necessary to measure some other physical property that is related to the strength and which can be obtained by NDT methods. One such property is the dynamic Young's modulus, that is the ratio of longitudinal stress to strain but derived from vibrational methods. Another quality index for concrete is the longitudinal pulse velocity, which is related to the elastic constants. Measurements of the hardness of the surface of concrete are made by a sclerometer. One such instrument is the Schmidt test hammer, which provides a rough idea of the quality of concrete. Radioactive isotopes are being used to estimate density of concrete and moisture content.

Keywords: concrete; density; dynamic modulus of E; hardness; elastic properties of concrete; pulse velocity; resonant frequency; radioactive isotopes; sclerometer; Schmidt rebound hammer; NDT methods.

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118. JONES, R., "Surface wave technique for measuring the elastic properties and thickness of roads: theoretical development", British Journal of Applied Physics, Vol. 13, Jan. 1962, pp. 21 - 29.

The elastic properties of concrete road slabs are deduced from measurements of the wavelength and velocity of vibrations of known frequency along the surface of the road. This paper develops the theory of the method of analysis of the relation between velocity and wave length for single- and two-layer pavements.

Keywords: density of concrete; elastic properties; frequency of vibration waves; surface wave technique; thickness of road slab; vibration method; wave velocity.

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119. LSSR (Latvian Soviet republic), "All-Union Conference on acoustic concrete testing methods" (Vsesojusnoe soveshchanie po akusticheskim metodam ispitaniya betonov), in Riga, Latvian SSR, July 5 - 7, 1962. Proceedings of 18 papers, publ. in Sbornik stattey VII, Izsledovaniya po betonu i zhelezobetonu; Izdatelstvo Akademii Nauk Latviyskio SSR, Institute stroitelstve i architekturi, Riga (in Russian).

Research Methods on Phys.-Mech. Properties of Materials

1) LATISHENKO, V.A., "Primary assumptions and perspectives of the multiparameter method for non-destructive testing of materials", pp. 7 - 15.
2) POCHTOVIK, G.J., "Theoretical basis for evaluation of stresses and structural-mechanical changes in concrete by ultra-sonic pulse velocity measurements", pp. 16 - 19.
3) LATISHENKO, V.A. and URZHUMTSEV, Yu. S. and MAKSIMOV, R.D., "The use of frequency dependency of the ultrasonic damping constant, for strength comparison of concrete", pp. 19 - 37.
4) URZHUMTSEV, Yu, S. and SPINCIS, I.A., "Proposed tentative standard for determination of the dynamic modulus of elasticity, shear modulus, Poisson's ratio and damping factor by ultrasonic pulse method", pp. 39 - 62.

5) LATISHENKO, V.A., "Determination of acoustic characteristics of material by resonant method for incorporating into GOST 4800-59 and GOST 6901-54 (USSR National Standards), pp. 63 - 71.

6) LATISHENKO, V.A. and URZHUMTSEV, Yu, s., "Proposed tentative national standard for non-destructive concrete strength determination by acoustically calibrating methods", pp. 73 - 84.

7) GLUCHOVSKOY, K.A., "Uniformity for non-destructive testing procedures", pp. 85 - 88.

8) KOROTKOV, S.N., KOSKIN, E.C., BABIKOVA, G.N., "Investigating some properties of concrete by the use of ultrasonic pulse velocity measurements", pp. 89 - 92.

9) EVSTGNEEV, V.D., ZHILIN, V.A., "Practical application of transonic test method for concrete strength control at precasting plants and at construction sites", pp. 93 - 96.

10) PFLAUMER, O.E., "Practical application of ultrasonics, investigating existing structures", pp. 97 - 101.

11) SHUBENKIN, P.F., BAZHENOV, Yu. M., "Testing concrete by ultrasonic pulse method", pp. 103 - 107.

12) NELSON, I.A., "Effect of some technological factors on the use of ultrasonics for concrete quality control", pp. 127 - 131.

13) WAINSHTOK, I.S., NADAREISHVILI, G.F., MIZROCH, Yu. I., "New ultrasonic equipment and its use for quality control of precast concrete products under heat processing", pp. 141 - 144.

14) URZHUMTSEV, Yu. S., "Application of a multiparameter acoustical method investigating strength increase of different cement pastes", pp. 145 - 149.

15) DOBROVOLSKI, A.S., "Investigation of some physical-mechanical properties of asbestos-cement products using ultrasonic pulse method", pp. 151 - 156.

16) MEDVEDEV, M.A., "Determination of acoustical characteristics and strength of concrete in structure by the velocity and damping coefficient of ultrasonic pulses in concrete reinforcement rods", pp. 157 - 164.

17) URZHUMTSEV, Yu. S., MEDVEDEV, M.Z., "Changes in ultrasonic pulse velocity and the rate of damping in concrete under loading", pp. 173 - 183.

18) DISCUSSIONS AND RESOLUTIONS, "All-Union Conference on Acoustical Concrete Testing Methods: in Riga, July 5 - 7, 1962. Participants from 80 scientific organizations in 32 cities of USSR presented 22 papers on NDT of concrete and the use of ultrasonic pulse velocity measurements for quality control. It was resolved to prepare as soon as possible GOST standards and specification for use of u/s pulse method in NDT of building materials and structures.

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120. ORCHARD, D.F., "The testing of concrete: non-destructive methods of test". In: "Concrete Technology" - Vol. 2, Chapter 4; pp. 181 - 215, Wiley & Sons, New York; First edit. 1962.

The NDT methods classified and discussed are as follows:

1) Hardness and allied tests: (a) Indentation method; (b) Rebound hammer; (c) Pull-out test; (d) Windsor probe test; (e) Localized load test.
2) Vibration methods: (a) continuous vibrations generated electronically at sonic frequencies; (b) Pulse of vibrations at ultrasonic frequencies; (c) Pulse of vibrations generated mechanically at sonic frequencies.
3) Radioactive methods: (a) Measurement of absorption of direct rays; (b) Measurement of amount of backscatter.

Keywords: hardness tests; indentation method; rebound method; pull-out test; Windsor Probe; sonic vibrations; gamma ray absorption; backscatter method.

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121. POHL, E., "Prüfung von Beton mit nieder - und hochfrequenten mechanischen Schwingungen:, (Testing of concrete using low- and high frequency vibrations); Wissenschaftliche Zeitschrift der Hochschule für Bauwesen, Leipzig, Heft 1, 1962, pp. 19 - 63.

Ultrasonic pulse velocity measurements show that a relationship exists for concrete strength parameter determination, provided mix characteristics are known and correlation curves are established.

Keywords: NDT; concrete strength; modulus of elasticity; vibration waves; ultrasonic pulse; pulse velocity.

1963

122. ACROYD, T.N.W. and Jones, R., "Non-destructive testing of structural concrete by the ultrasonic pulse technique". Proceedings, Fourth International Conference on Non-Destructive Testing, held in London, England, Sept. 1963, pp. 230 - 234. Butterworth, London, England.

There is no unique relationship between pulse velocity and concrete strength, but a useful empirical relationship can be established when the concrete mix composition and curing conditions are carefully controlled. Under such controlled conditions an accuracy of strength estimate of about 15% is usually claimed, although more optimistic estimates of 10% have been claimed by Russian sources.

Keywords: accuracy of strength estimate; concrete strength; crack detection; non-destructive testing; pulse velocity site testing; structural concrete testing; ultrasonic pulse velocity technique.

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123. Highschool for Construction, Leipzig, G.D.R. Publ. by the Rector, Wissenschaftliche Zeitschrift (Sonderdruck). Special issue on non-destructive testing of concrete, 1963; 6 articles, pp. 163 - 197. (in German).

Articles published are as follows:

1) "Measuring dynamic elasticity constants of materials by resonant vibration methods", H.Kottas, pp. 163 - 167.
2) "Some applications of N-D dynamic methods for testing concrete", G. Martincek, Bratislava, pp. 169 - 175.
3) "Determination of Poisson's Ratio by ultrasonic pulse velocity measurements", W. Rentsch, Pirna, pp. 177 - 181.
4) "Quality determination of concrete by dynamic methods", E. Slachta, Praha, pp. 183 - 186.
5) "Quality determination of mass concrete by ultrasound", A.K. Tretjakow, Moscow, pp. 187 - 189.
6) "Simultaneous application of different N-D tests for quality control of concrete", L. Brunarski, Warszawa, pp. 191 - 196.

Keywords: NDT, concrete strength; dynamic tests; resonant vibration tests; dynamic E modulus; Poisson's ratio; ultrasonic pulse velocity.

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124. JOHNSON, V.D., "Evaluation of hardened field concrete with the rebound hammer", Indian Concrete Journal, Vol. 37, No. 11, Nov. 1953, pp. 407 - 411.

An investigation regarding the usefulness of the rebound hammer for evaluating field concrete strength is reported. A close-fitting

calibration curve is possible when average values of a large number of results are plotted. The factors affecting the rebound number - compressive strength relation are discussed.

Keywords: concrete; compressive strength; surface hardness; impact test; rebound hammer; Schmidt test hammer; calibration curve.

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125. JONES, R., "Following changes in the properties of road bases and sub-bases by the surface wave propagation method", Civil Engineering, London, England, Vol. 58, May 1963, pp. 613 - 617; June 1963, pp. 777 - 780.

This method has been developed for obtaining the elastic properties and measuring the thickness of the road slabs. Measurements are made of the wavelength and velocity of the vibrations at the surface of the road at frequencies of 30 to 30,000 c/sec. The relation between velocity and wavelength yields the required information. Tests over a period of years indicate the changes in the properties of the base materials caused by time and traffic.

Keywords: cement-bound bases; elastic properties of road layers; surface waves; non-destructive testing; vibration methods.

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126. JONES, R., "The ultrasonic testing of concrete", Ultrasonics, Vol. 1, Apr./June, 1963, pp. 78 - 82.

The main object of ultrasonic testing of concrete is to provide a non-destructive method of assessing the quality of structural concrete from measurements of pulse velocity. In this article experimental techniques for the measurements of pulse velocity are discussed. A pulse reflection technique is described which enables the thickness of concrete slabs to be obtained under favourable

conditions. Limited success has also been achieved in assessing the extent and severity of visible cracks in concrete.

Keywords: concrete cracks; strength; dynamic E modulus; pulse reflection; pulse velocity; ultrasonic testing; NDT.

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127. MUENOW, R., "A sonic method to determine pavement thickness", Journ. Portland Cement Assoc., Vol. 55, No. 3, Sept. 1963, pp. 8 -21.

Presents a technique for determining the thickness of concrete slabs by non-destructive means. It utilizes the fundamental wave relationship in that a measure of the longitudinal resonant-frequency wave length, which is twice the thickness, can be determined from values of pulse velocity and resonant frequency. The difference between the non-destructive determination and the core length averages 2 to 3%.

Keywords: longitudinal resonant frequency; non-destructive test method; pavement thickness; pulse velocity; resonant frequency; soniscope; wave length.

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128. PREISS, K. and NEWMAN, K., "An improved technique for the measurement of density of concrete and soils with gamma-radiation", Proceedings, Fourth International Conference on Non-Destructive Testing, London, Sept. 9-13, 1963, pp. 135 - 141. Publ.: Butterworths, London, England.

This paper describes the development of an instrument and testing technique for measuring the density of concretes and soils in situ by Compton back-scattering, using a gamma-ray source. Only empirical relationships can be derived between radiation density

measurements and such properties as concrete compressive strength and static modulus of elasticity.

Keywords: back-scatter method; Compton scattering process; density measurements; detector counter; gamma-ray source; radiation measuring; surface layer density; empirical relationship.

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129. SHANKAR, N.K., "Non-destructive testing of concrete by ultrasonic methods", Indian Concrete Journal, Vol. 37, No. 7, July 1963, pp. 262 - 264.

The velocity of ultrasonic waves in concrete is dependent on the quality of the concrete. There is a relationship between the velocity of ultrasonic waves in concrete and the compressive strength of the concrete. This article gives a formula which determines the relationship for all types of concrete.

Keywords: concrete compressive strength; pulse velocity; non-destructive testing; concretescope; ultrasonic pulse.

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130. SHRIVASTAVA, J.P. and SEN, B., "Factors affecting resonant frequency and compressive strength for concrete", Part I & Part II, Indian concrete Journal, Vol. 37, No. 1, (Jan.) and No. 3 (March), 1963.

Results are presented on the influence of various factors such as age, W/C ratio, mix proportions, etc, on resonant frequency, logarithmic decrement and compressive strength. The findings show that two different types of correlation curves are obtained for low-and high-strength concretes. Curves were obtained correlating the resonant frequency at early ages with compressive strength at later ages.

Keywords: age of concrete; compressive strength; correlation curves; dynamic test methods; factors affecting test results; water/cement ratio.

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131. SLATE, F.O. and OLSEFSKI, S., "X-rays for study of internal structure and microcracking of concrete:, ACI Journal, Proceedings, Vol. 60, No. 5, May 1963, pp. 575 - 588.

Use of X-radiography and microscopic examination of thin slices of concrete revealed cracks formed during drying, at the interfaces between aggregate and mortar, before any loading. The X-ray technique described is a powerful new tool for study of the internal structure, and changes in concrete due to drying and external loading.

Keywords: concrete internal structure; micro-cracking; microscopic study; plain concrete; X-ray photography.

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132. Pochtovik, G.J., Pflaumer, O.E., Smolenskaya, N.G., Filonidev, A.M., "Results of All-Union competition for the best ultrasonic testing equipment for the control of concrete quality", Beton i Zhelezobeton, No. 5, 1963, pp. 235-239 (in Russian).

The competition was announced in May, 1962 and carried out by the central scientific technical organizations of the concrete industry and the Academy for Construction and Architecture, USSR. In the competition, organizations from Moscow, Kijev and Riga, took part; different designs of ultrasonic equipment were shown in this article. After examination of the different apparatus, the jury recommended production of the following best types: "Beton" (Moscow), "UKB-2" (Riga) and "UP-4" (Moscow).

Keywords: concrete quality control; ultrasonic test equipment; UZP-62 (Moscow); "Beton" NIIZH (Moscow); UKB-1 (Riga); ZIKB-1 (Moscow); PIK-11 (Moscow); UP-4 (Kijev); KPD-1 (Moscow); UKB-2 (Riga).

1964

133. BOUNDY, C.A.P., and HONDROS, G., "Rapid field assessment of strength of concrete by accelerated curing and schmidt rebound hammer", Journal of American concrete Institute, Proceedings Vol. 61, Jan. 1964, pp. 77 - 84.

Tests were made on 6-in. test cubes from 17 different batches of concrete. Some of the cubes were water cured and tested in a compression machine at 28 days. Remaining cubes were steam-cured and tested with rebound hammer prior to being loaded to failure in a compression machine. The results suggest that the rebound hammer may be used with accelerated curing to provide a rapid and convenient field method for estimating the strength of concrete.

Keywords: concrete compressive strength, curing; quality control; rebound hammer; steam curing; water curing.

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134. DYLANDER, B., "Detection of cracks in concrete surfaces by means of fluorescent particles", RILEM Bulletin No. 24, Sept. 1964, pp. 171 - 172.

In the fluorescent method, concrete surface is prepared in such a way that actual cracks are marked by fluorescent particles that appear luminous in the dark when exposed to ultra-violet light. The preparation is carried out in two stages: 1) application of powdered chalk and 2) application of fluorescent particles.

Keywords: concrete cracks; detection of cracks; microscopic observation; fluorescent particles; ultra-violet light.

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135. JONES, R., "Non-destructive Testing of Concrete", RILEM working group meeting, Delft, Netherland, April 25, 1963, Chairman's report, RILEM Bulletin No. 22, 1964, pp. 45 - 47.

Proceedings of meeting:

1) Measurement of moisture content - dielectric constant method; neutron absorption method; microwave moisture meter.
2) Pulse velocity methods for estimation of the strength of concrete. Attenuation of pulse is related to changes in density.
3) Radiography of concrete. Gamma radiography of concrete is frequently used to determine the position and dimensions of reinforcement in concrete.
4) Testing roads by a mechanical surface wave method.

Keywords: concrete properties; density; dielectric constant; moisture content; neutron absorption; microwave moisture meter; pulse velocity; radiography of concrete; surface waves.

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136. KORNILOVICH, Yu. E., BELOCHVOSTIKOVA, V.I., "Ultrasound in the technology of concrete", Gosudarstvennoe Izdatelstvo Literaturi po Stroitelstvu i Architekturi, Kijev, USSR, 57 pp. book, 1964 (in Russian).

Application of ultrasound vibration in the technology of concrete production is discussed. The use of vibration for activating cement paste may greatly improve the uniformity of concrete mixes, resulting in increased strength of hardened concrete. Ultrasound increases the plasticity of concrete mixtures, resulting in lower W/C ratio and more complete hydration of cement, because of better

dispersion of cement particles. Tests have shown that vibrosound processing of concrete mixes result in a min. strength increase of 30%. The best application of this method is in a continuous-mixing installation with forced mixers.

Keywords: activation of cement paste; cement hydration; concrete mixture; continuous mixing; hardening of concrete; high-strength concrete; particle dispersion; plasticity of mixture; magnetostriction; ultrasound vibration; viscosity.

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137. MALHOTRA, V.M., "Non-destructive methods of testing concrete", Cement and Concrete, New Delhi, Vol. 5, No. 1, (April-June), Part I, 1964, 1964, pp. 22 - 23.

This Part I deals with hardness tests for concrete. (Parts II and III cover vibration tests and x-ray and gamma-ray penetration tests). Different methods of hardness testing are mentioned and the Schmidt-test hammer based on the rebound principle is described in detail. The calibration procedure for the hammer is given and its advantages and limitations are discussed.

Keywords: compressive strength; hardness tests; indentation test methods; Schmidt test hammer; William's pistol; Frank spring hammer; Einbeck pendulum hammer.

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138. TOBIO, J.M., "Medidas y ensayos no destructivos" (Measuring the properties of concrete by non-destructive methods), Monografias del Instituto Eduardo Torroja de la construccion y del cemento, No. 237, Madrid, 1964, 52 pp.

Tests were carried out at the Metrology laboratory of the Institute Eduardo Torroja of Construction and Cement, in measuring concrete properties by non-destructive methods. The largest part of this

paper is devoted to the control of the quality of concrete at the building site. A full description is given of the sonic and ultrasonic methods employed. Other types of tests are also mentioned, which could prove very helpful to concrete technicians and to the construction industry in general.

Keywords: NDT of concrete; tests on building site; sonic tests; ultrasonic tests; nuclear tests.

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139. U.S. ARMY ENGINEERS WATERWAYS EXPERIMENT STATION, Vicksburg, Miss., "Investigation of cement-replacement materials - Significance of pulse-velocity data for mass concrete blocks", Misc. Paper No. 6 - 123, Report 9, Feb. 1964.

Some of the results obtained in this study were mentioned in a paper "Use of the soniscope by Concrete Division, WES", by Bryant Mather et al. HRB Bull. 206 (pp. 42 - 45), 1959. Co-operative tests were made by Whitehurst and Oleson at the WES laboratories to investigate further the pulse velocity of limestone. A hypothesis about pulse velocity through inhomogeneous bodies is given by R.E. Phillio in Appendix "A".

Keywords: aggregate effect on pulse velocity; limestone aggregate; pulse velocity; path length; transmission time.

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140. TRETJAKOV, A.K. and FILONIDOV, A.M., "Control of concrete by ultrasound in hydrotechnical construction", Izdatelstvo Energiya", Moscow/Leningrad, 87 pp. book, 1964 (in Russian).

In this book is discussed concrete quality control of hydrotechnical structures by the use of ultrasonic test methods. Results are shown from tests carried out on a number of hydraulic structures, such as dams, retaining walls and bridge piers. The

density, uniformity and strength of concrete monoliths are being tested and tabulated.

Keywords: concrete strength; density; durability; hydraulic structures; ultrasonic pulse velocity; NDT methods.

1965

141. COLE, D.G. and SPOONER, D.C., "The damping capacity of hardened cement paste and mortar in specimens vibrating at very low frequencies", ASTM proceedings, Vol. 65, 1965, pp. 661 - 667.

The damping capacity of cement paste and mortar prisms vibrating at frequencies from 0.16 to 4 cps and with strain amplitudes up to 150 x 10^{-6} were measured. The logarithmic decrement increased linearly with strain amplitude over the range of strain investigated. At frequencies below 2.5 cps the logarithmic decrement increased with decreasing frequency. The authors suggest the processes responsible for the low-frequency damping effects are the same ones that govern creep.

Keywords: damping capacity; cement; mortar; strains; amplitude; frequency; vibrations; creep.

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142. BALAZOVSKI, M. Ya., "Reference standards of resolutions by X-raying and Gamma-raying". (The Soviet Journal of Non-destructive Testing). Defektoskopiya, No. 1 (Jan./Feb), 1965, pp. 57 - 71, Izdatelstvo Akademii Nauk Moscow, USSR. (46 References in Russian).

For estimating detectability, the investigating component is monitored along with a standard of detectability, which simulates

natural defects to a certain extent. Standards of detectability fall into three groups:

1) Standards for estimating the detectability of a method of monitoring to ensure constant conditions;
2) Standard for determining the quality of a single picture;
3) Standard for investigating the influence of various factors.

Keywords: X-raying; Gamma-raying; defectability; radiograph; sensitivity; slot standard; bacterial standard.

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143. JONES, R., "Thickness and quality of cemented surfacings and bases - measuring by a non-destructive surface wave method", Civil Engineering (London), Vol. 60, 1965, No. 705, pp. 523, 525, 527, 529.

Experimental data obtained on concrete road slabs give a relation between velocity and wavelength from which the thickness and elastic properties of the layer of concrete are calculated. Empirical relations between elastic and strength properties determined on test specimens of the same materials provide means of estimating the in-situ quality of the material from the experimental data.

Keywords: density of concrete; dynamic modulus of elasticity; frequency of surface waves; measuring thickness; vibration velocity; wave length and velocity.

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144. JONES. R., "RILEM working group on the non-destructive testing of concrete", Chairman's report of a meeting of the group, held Sept. 22-25, 1964 in Bucharest, Romania. RILEM Bulletin No. 27, June 1965, pp. 121 - 125.

This summary report covers discussions of 25 papers (see No. 149, References) presented at the meeting on the following NDT methods:

1) Resonance methods; (2 papers - Nos. 1 & 2).
2) Pulse methods - a) new developments (3 papers - Nos. 3, 4 & 5); b) detection of defects and cracks (2 papers, Nos. 6 & 7); c) estimation of strength of in-situ concrete (5 papers - Nos. 8 - 12).
3) Rebound and indentation methods; (3 papers - Nos. 13, 14 & 15).
4) Radioactive methods; (2 papers - Nos. 16 - 23).
5) Dielectric constant methods (no papers - discussion only).
6) Vibrational testing of roads (No. 24).
7) Other methods (1 paper - No. 25, crack detection).

Keywords: NDT methods.

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145. HENNICKE, H.W. and LEERS, K.J., "Die Bestimmung elastischer Konstanten mit dynamischen Methoden" (Determination of elastic constants by dynamic methods). Mitteilung aus der Bergakademie, Clausthal; Tonind.-Zeitung, Vol. 89, Heft 23/24, 1965, pp. 539 - 543, 35 ref.

The required procedure to calculate modulus of elasticity from the pulse velocity and resonant frequency measurements is described. The needed physical and mathematical formulas are developed for use in calculations. For strength calculation empirical relations are available.

Keywords: dynam. mod. E.; Young's modulus; resonant frequency; ultrasonic pulse velocity; pulse travel time.

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146. LVOV, G.S. and CHUEV, L.V., "New reference standards for ultrasonic nondestructive testing, I", Defektoskopiya, (The Soviet Journal of Nondestructive Testing), No. 1, Jan./Feb., 1965, pp. 53 - 56; Izdatelatvo Akademii Nauk, Moscow, USSR. (In Russian).

The standard is in the form of a strip of variable width. Its back-scattering is compared with that of a face of a straight cylinder and a strip of constant width. A standard with a continuously changing dimension can be built. In this paper the results of investigation on the scattering on an infinite strip are described. Measurements were made in the immersion variant at frequencies of 1.5, 1.5, 4.0 megacycles, using an instrument DUK - 6V.

Keywords: ultrasonic Flaw-detection; back-scattering standards; standard reflectors.

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147. MAKSIMOV, R.D., "Determination of aggregate moisture for preparation of concrete mixes". Sbornik statey VIII, Izsledovaniya po betonu i zhelezobetonu; Akademiya Nauk Latviyskoy SSR, Izdatelstvo Zinatne, Riga, 1965, pp. 155 - 168 (in Russian).

To maintain the designed W/C ratio for a certain quality concrete, the aggregate moisture content has to be accounted for and deducted from the total free water content in the mixture. There are in operation different moisture indicators operating on the electrical resistance principle. Because additional factors such as impurities and mineralogical composition influence the results, moisture content may be determined with a $\pm$ 2% variation, which is too large for accuracy. Much better results are obtained with moisture meters operating on fast neutron back-scatter or radiation

principle. Application of such equipment and calculation of moisture content in aggregates are shown.

Keywords: concrete strength; aggregate moisture content; concrete mix design; W/C ratio; moisture meters; electric resistivity meters; fast neutron radiation; back-scatter method.

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148. MEDVEDEV, M.Z., "Use of resonant method to test rigidity and crack resistance of bending elements in reinforced concrete structures", Sbornik statey VIII, Izsledovaniya po betonu i zhelezobetonu; Akademiya Nauk Latviyskoy SSR, Izdatelstvo Zinatne, Riga, 1965, pp. 193 - 228 (in Russian).

In order to establish an effective production control system at the plant, non-destructive test methods are being used. Relationship between parameters of bending deformation and dynamic characteristics obtained on bent element produces required control, which provide acceptable deformation limits for crack resistance in reinforced concrete members.

Keywords: concrete strength; bending deformations; crack resistance; N-D testing; dynamic test methods; resonant frequency method; dynamic modulus of elasticity.

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149. RILEM, Papers presented and discussed by the NDT working group at RILEM meeting, 22-25th Sept. 1964 in Bucharest, Romania. Bull. No. 27, June 1965, 124 pp., References.

1) MARTINCEK, G., "The determination of Poisson's ratio and the dynamic modulus of elasticity on the basis of the frequencies of natural vibration in thick circular plates".
2) BRUNARSKI, L., "Draft instructions on the application of sclerometric, ultrasonic and resonance methods".

3) FACAOARU, I., TEODORU, G. and BUBLAC, L., "Recherches sur l'utilisation des mesures d'atténuation des ultrasons pour la détermination de la résistance du béton".

4) T.N.O. Reports B1-64-60-/12-1-33. "Evaluation of the compressive strength of concrete derived from pulse velocity and damping coefficient".

5) JONES, R. "The ultrasonic testing of concrete". See also: Ultrasonics, 1963, 1, 78 - 82.

6) FACAOARU, I., CONSTANTINESCO, L., TEODORU, G. and BUBULAC, L., "Rusultats dans l'application des méthodes ultrasconores d'impulsion au contrôle de la qualité des bétons, sur les chantiers de Roumaine".

7) T.N.O. Report B1-64-59/12-1-35. "Assessment of frost damage of concrete in situ with the hammer pulse apparatus".

8) PETKOV, V., "Studies on the utilisation of the ultrasonic pulse method to determine the strength of concrete".

9) CIGANEK, M., "Prüfungen grosser Bauwerke, b.z.w. Bautailen mittels Ultraschall". See also: Zement und Beton, Sept. 27, 1963, 1 - 17.

10) STEFANESCU-GOANGA, A., "Remarks on the variation of the coefficient K belonging to the transformation relation modulus of elasticity - compressive strength".

11) KOCHIS, B., "Relation entre la résistance du béton et la vitesse de la propagation du son".

12) FACAOARU, I., "L'expérience de l'application des normas roumaines provisoires pour l'essai du béton a l'aide des ultrasons".

13) WESCHE, K. "Comparison of impact test results of concrete in a construction according to the German Standard D.I.N. 4240".

14) FACAOARU, I., "L'expérience de l'application des normes roumaines provisoires pour la détermination de la résistance du béton a l'aide du sclerometre Schmidt".

15) SKRAMTAJEV, B.G. and LESCHINSKY, M.Y., "Complex methods of non-destructive tests of concrete in construction and structural works", RILEM International Conference on problems

of accelerated hardening of concrete in manufacturing precast reinforced concrete units, Moscow, 1964.

16) HONIG, A., "Radiographische Makrostrukturenterschung von Stahlbetonkonstruktionen". See also: Kerntechnik, Isotopentechnik und Chimie, Vol. 11, 1962, 499 - 503.

17) POHL, E., "Kontrolle der Raumdichte von Betonbauteilen mit Gamma-strahlen".

18) NEMES, A. and DONIGA, N., "Considerations sur le contrôle non-destructif des joints de soudure dans les installations de l'industrie chimique".

19) MAKAROV, R., BASIN, Y. and SELEZNEV, N., "On standardization of radio-active methods in building practice".

20) MAKAROV, R. and BASIN, Y., "Radioactive methods of measurement in buildings".

21) HONIG, A., "Anwendung der Radionuklide bei der Prüfung von Beton und Beton Konstruktionen in der C.S.S.R.", Wissenschaftliche Zeitschrift der Hochschule für Bauwesen, Leipzig; Sonderdruck, 1963, 205 - 223.

22) FRENKING, H., "Method for measuring the density of concrete pavements by means of radioisotopes".

23) BOODT, M.De., "Auxiliary moderators to improve the precision and resolving power of the neutron scattering moisture meter".

24) JONES, R., "Following changes in the properties of road bases and sub-bases by the surface wave propagation method". Civil Engineering (London), Vol. 58, 1963; (682, p. 613 - 617); (683, p. 777 - 780).

25) DYLANDER, B., "Detection of cracks in concrete surfaces by means of fluorescent particles".

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150. PREISS, K., "Measuring concrete density by gamma-ray transmission". ASTM, Materials Research & Standards, Vol. 5, No. 6, June 1965, pp. 285 - 291.

Measuring concrete density by gamma ray transmission is a simple procedure. Concrete test specimen is placed in the path of radiation emitted from a gamma ray source. The radiation is scattered or absorbed in a manner dependent upon the density of the materials. If, therefore, a source and the detector are placed on opposite sides of the concrete specimen, the detected radiation intensity will be a measure of the concrete density.

Keywords: concrete density; gamma rays; radiation; detector; scintillator.

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151. WEIGLER, H. and KERN, E. "Uber die Anwendungsmöglichkeiten des Ultraschallverfahrens zur Beurteilung der Betongüte" (The possibilities of application of the ultrasonic method of estimating the quality of concrete), Betonstein-Zeitung, Vol. 31, No. 5, 1965, pp. 279 - 285 (THE, Darmstadt).

The suitability of the ultrasonic pulse propagation method for the determination of the strength of concrete and for the detection of cavities was investigated. It appears that the pulse velocity is primarily governed by the nature of aggregate, by the aggregate content of the concrete and also by the quality of the hardened cement paste, which is of prime importance to the quality of the concrete. It was not possible to establish a satisfactory correlation between the compressive strength and the propagation velocity of the pulses.

Keywords: NDT of concrete; compr. strength of concrete; sonic pulse velocity; cavity detection; ultrasonic pulse velocity methods.

1966

152. HARLAND, D.G., "A radioactive method for measuring variations in density in concrete cores, cubes and beams", Magazine of Concrete Research, Vol. 18, No. 55, 1966, pp. 95 - 101.

Describes an apparatus for measuring the variation of density along cores and beams of concrete. It is determined by measuring the change in the absorption of gamma radiation. The variation in the intensity of the transmitted radiation is translated into density variations, by a suitable calculation.

Keywords: density of concrete; gamma radiation; absorption of gamma rays.

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153. JONES, R., "RILEM working group on non-destructive testing of concrete", Chairman's report of meeting held April 26-28, 1966 in Aachen, West Germany, RILEM Bulletin No. 33, Dec. 1966, pp. 267 - 369.

This summary report covers discussions of 27 papers (see Ref. No. 154) presented at the meeting on the following non-destructive test methods:

1) Resonance methods (3 papers - Nos. 1,2,3)
2) Pulse methods (9 papers - Nos. 4 - 12)
3) Hardness methods (4 papers - Nos. 13 - 16)
4) Combined methods (2 papers - Nos. 17 - 18)
5) Radio-active methods (5 papers - Nos. 19 - 23)
6) Dielectric constant methods (1 paper - No. 24)
7) Vibrational testing of roads (2 papers - Nos. 2 & 26)
8) Magnetic methods (1 paper - No. 27)

Keywords: NDT methods.

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154. RILEM, Papers presented and discussed by the NDT working group at RILEM meeting, April 26-28, 1966, in Aachen, West Germany; RILEM Bull. No. 33, Dec. 1966, pp. 369 - 370.

1) MARTINCEK, G. "Die Bestimmung der Elastizitätsmoduln aus Eigenschwingungen von Würfeln und Prismen", Acustica, Vol. 13, No. 3, 1963, 123 - 130.
2) POKORNY, M. "A universal apparatus for measuring the resonant frequencies, the damping coefficient and pulse velocity of stress wave propagation".
3) BRUNARSKI, L. "Recommendations for the standardization of resonance methods".
4) REIDING, F.J. "Preamplifiers for using long cables in ultrasonic concrete testing (Cawkell)". T.N.O. report No. BI-66-27-103.
5) REIDING, F.J. "Battery-operated concrete tester". T.N.O. Report BI-66-17-103.
6) PAVLIK, A. "Analysis of the results of ultrasonic testing of concrete from the viewpoint of compactness".
7) GALAN, A. "The determination of concrete strength by means of ultrasonic pulse velocity and damping coefficient".
8) KOCHIS, B. "Ultrasonic testing of concrete".
9) WEIGLER, H. and KERN, E. "Ueber die Anwendungsmöglichkeiten des Ultraschallverfahrens zur Beurteilung der Betongüte". Betonstein-Zeitung, 1965, H.5.
10) JAVOR, T. "Ultilization of impulse methods for regulating the speed of construction of prestressed bridges".
11) FACAOARU, I. "Aspects of the microcracking and failure of concrete under compression determined by means of ultrasonic pulse velocity measurements".
12) JONES, R. "Cracking and failure of concrete test specimens under quasi-static loading".
13) PAVLIK, A. "The influence of the structure and the technology of concrete on the accuracy of sclerometric tests".

14) WEIGLER, H., SIEMERS, H., SPITZNER, J. "Zur nachträglichen Bestimmung der Betondruckfestigkeit". Betonstein-Zeitung, H.3, 1966.

15) STORK, J. "The determination of local strength in solid heterogeneous materials with the help of a torsional microsclerometer."

16) KOLEK, J. "An analysis of the replies to the questionnaire on the use of the Schmidt test hammer".

17) CAMPUS, F., DUTRON, R, COUNE, A. "Controvôle de la qualité du béton en laboratoire et sur chantier". Bruxelles, 1964.

18) FACAOARU, I., DUMITRESCU, I., CONSTANTINESCU, L. "Results in using combined non-destructive testing methods for predicting the compressive strength of concrete".

19) BREDA, M. "Non-destructive investigation of the homogeneity of concrete structures by means of a radiometric method".

20) POHL, E. "Determining the effect of changing the geometry of the test arrangements on measurements of volume density of large area concrete building elements by means of gamma radiation".

21) HONIG, A. "Electric exposure meter for gamma-ray radiography".

22) HONIG, A. "Ultrasonic and radiometric measurement of homogeneity and density of concrete in the biological shield of a nuclear reactor".

23) DE BOEVER, J. and DE BOOT, M. "The application of cadmium and cast nylon in the measurement of soil moisture with a neutron moisture meter".

24) T.N.O. Reports (Holland), "Measurements of the moisture content of concrete by means of micro-wave absorption".

25) JONES, R., MAYHEW, H. "Thickness and quality of cemented surfacings and bases, measuring by a non-destructive surface wave method". Civil Engineering, 1965, 60 (705).

26) JONES, R., THROWER, E.N. "An analysis of waves in a two-layer composite plate and its application to surface propagation experiments on roads". Journ. Sound, Vol. 2, 1965.

27) REIDING, F.J. "A portable reinforcement cover meter". T.N.O. Report No. BI-66-25-103 (Holland).

28) HONIG, A. "Electric exposure meter for gamma-ray radiography".

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155. MANNS, W., SASSE, H.R. "Uber die Auswertung der Kugelschlagprüfung bei Beton aus Sonderzementen" (Evaluation of the ball-impact hardness testing of concrete made with special cements), Beton, Vol. 16 (2), Feb. 1966, pp. 63-67 (IBAC, Aachen).

Concrete hardness tests carried out on older concrete at the THS, Aachen, using a Frank spring hammer, have indicated quite a difference with compressive strength determination when a supersulfated (Sulfathüttenzement) or aluminous cement (Tonerdezement) was used in concrete. Direct compressive strength test results of companion test specimens did not correlate with those normally obtained on portland cement concrete; therefore, it is not recommended to use the ball-impact test hammer on such concrete without a special calibration curve and age factor.

Keywords: ball-impact hardness test; aluminous cement concrete; supersulfated cement concrete; ball indentation.

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156. PREISS, K., "Measuring the thickness of a concrete slab by gamma-ray transmission", Journal of American Concrete Institute, Vol. 63, No. 7, July 1966, pp. 743 - 748.

Describes a method for determining the thickness of a concrete slab by measuring the amount of gamma radiation that passes through it. Results in the labs showed that slabs could be measured to an accuracy of better than 2 percent.

Keywords: concrete; gamma-ray; transmission; measurement; slab; thickness.

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157. "SONIC TESTING", Journal of American Concrete Institute, Vol. 63, Feb. 1966, pp. 293 - 298.

Abstract of "Evaluation of concrete properties from sonic tests", by Prof. E.A. Whitehurst, ACI Monograph No. 2, 1966. The term "sonic testing" refers to testing concrete by means of sound waves within and beyond the normal audible frequencies. Two kinds of sonic testing are discussed: resonant frequency techniques, which involve determination of the resonant frequency of concrete specimen; and pulse velocity techniques, i.e., tests to determine the velocity with which a small mechanical impulse travels through the concrete.

Keywords: concrete properties; pulse velocity; resonant frequency; sonic testing; soniscope; uniformity of concrete.

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158. NORMAL, E.A., "Evaluation of concrete properties from sonic tests". ACI Monograph No. 2, 1966, 94 pp.

Contents:

1) Origin and development of sonic test methods.
2) Use of sonic test results in calculation of dynamic properties of concrete.
3) Evaluation of static modulus of elasticity and strength of concrete.
4) Evaluation of other characteristics of concrete from sonic tests.
5) State of the art of sonic testing of concrete. The greatest usefulness of sonic tests is associated with the evaluation of the uniformity of concrete.

Keywords: concrete properties; cracks in concrete; dynamic properties of concrete; pulse velocity; resonant frequency; sonic tests; soniscope; uniformity of concrete.

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159. WHITEHURST, E.A., "Dynamic test", ASTM Special Publication STP 169-A, 1966, pp. 176 - 188.

Dynamic tests of concrete may be subdivided into three groups: 1) sonic tests, involving determination of the resonant frequency of a specimen; 2) pulse transmission test, measuring the velocity of a compressional pulse travelling through the concrete; 3) surface impact tests, measuring rebound distance of a hammer, or the diameter of indentation of a blow. Many factors influence the results of dynamic tests in varying degrees. Such factors are: type of aggregate has the most pronounced influence. Other are: moisture content, temperature, density, type of cement, aggr./cem. and water/cam. ratio and mixtures.

Keywords: calibration curves; concrete properties; compressive strength; cracks in concrete; dynamic tests; dynamic modulus of elasticity; impact tests; pulse transmission test; pulse velocity; rebound hammer tests; resonant frequency tests; sonic tests.

1967

160. GALAN, A.J., "Estimate of concrete strength by ultrasonic pulse velocity and damping constant", Proceedings, ACI Journal, Vol. 64, No. 10, Oct. 1967, pp. 678 - 684.

Describes NDT methods for estimating concrete strength and factors to be determined which reflect the strength of material. Ultrasonic pulse velocity and the u-sonic pulse damping constant

can be used. These two acoustic characteristics reflect both elastic and inelastic properties. The relation between concrete strength in compression and the two characteristics is expressed by a regression equation. The two-parameter regression equation is most applicable when specimens are tested at early age or in water saturated condition, and also at a specified time in a hardened state.

Keywords: concrete strength; damping constant; pulse velocity; NDT; elastic properties; inelastic properties.

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161. KORDINA, N., ROY, V. and WAUBKE, N.V., "Ultraschallmessungen an bewehrten Kiesbeton" (Ultrasonic measurements on reinforced gravel-aggregate concrete), Materialprüf, Vol. 9, No. 3, March 1967, pp. 81 - 83. (THE, Braunschweig).

Application of ultrasonic pulse velocity measurements as a practical test method has been investigated and research on its usefulness for crack detection was done. A distinct and reproducible dependency of the variation of test data on the degree of pre-load was established with 27 concrete mixes. The investigations have been extended to different transversal reinforcement contents. Less than 7% transversal steel reinforcement influenced the absolute values of pulse velocity only slightly.

Keywords: NDT; crack detection in concrete; pulse velocity measurements; effect of reinforcement on pulse velocity.

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162. LEERS, K.J. and HENNICKE, H.W., "Zur Materialprüfung mit mechanischen Schwingungen an werkstoffen der Stein und Erden-Industrie" (Testing stone and ceramic materials using mechanical vibrations). Mitteilung aus der Technischen

Universität Clausthal; Tonindustrie.-Zeitung, Vol. 91, Heft No. 6, 1967, pp. 211 - 218; 31 ref.

N-D testing with mechanical waves has occupied an important place for testing of raw and engineering materials of the construction industry. A brief account is given on the mechanical vibration, the different types of waves and the wave generation. Methods for calculating the velocity of mechanical waves and the elastic constants are given. The determination of damping constant is also explained.

Keywords: NDT; mechanical vibration; waves; resonant frequency; wave velocity; damping constant.

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163. LVOV, G.S. and CHUEV, L.V., "Standards for ultrasonic flaw detection, II" (The Soviet Journal of Nondestructive Testing), Defektoskopiya, No. 1 (Jan./Feb.), 1967, pp. 3 - 7, Izdatelstvo Akademii Nauk, Moscow, USSR. (in Russian).

A standard reflector in the form of a disk placed at the vertex of a cone is described. A method is proposed for the use of this standard, as well as a standard reflector in the form of an expandable strip for estimating the dimensions of defects.

Keywords: ultrasonic flaw detection; reflector disk; back-scattering standards; standard reflectors.

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164. MALHOTRA, V.M., "Non-destructive methods of testing concrete", Cement and Concrete, New Delhi, India, Vol. 8; Part II: No. 1 (April/June, pp. 51 - 61) and No. 2 (July/Sept, pp. 120 - 127); Part III: No. 3 (Oct./Dec., pp. 2 - 4), 1967.

Parts II and III from the series of three parts on N-D testing of concrete cover the following methods;

Part II: Resonant frequency method; mechanical sonic pulse velocity method, and ultrasonic pulse velocity method.

Part III: Radioactive methods - Application of gamma radiography:

a) Density of concrete by absorption of gamma rays;

b) Back-scatter method for determining the density of surface layer of concrete;

c) Determination by gamma radiography of position and condition of reinforcement in concrete.

Keywords: absorption of gamma rays; back-scatter method; density; gamma rays; gamma radiography; detection of reinforcement; sonic pulse; dynamic methods; ultrasonic pulse velocity.

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165. MARTIN, A.G., "Improved techniques for the ultrasonic measurement of elastic constants". ASTM 70th Annual Meeting, Boston, Mass., June 25 to 30, Paper No. 50. 1967.

The elastic constants are calculated from the velocity measurements of longitudinal and shear waves. There are a number of problems in the application of the method, some of which (anisotropy and non-homogeneity of the material, specimen design and instrumentation) are discussed. To describe the elastic properties of a material in terms of two independent constants, the material must be isotropic and homogeneous.

Keywords: elastic properties of material; anisotropy; homogeneity; attenuation of waves; ultrasonic waves; velocity of waves; longitudinal waves; instrumentation.

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166. McHENRY, D. and OLESON, C.C., "Pulse velocity measurements on concrete dams". Paper presented at the 9th Congress on Large Dams, Istamboul, 1967, Q.34/R.5, pp. 75 - 89.

The objective of the paper is to present pulse velocity measurement as one diagnostic procedure which may be used as an aid in assessing the quality of concrete in a structure. The fundamental relationships between the velocity of elastic wave propagation and certain physical properties of homogeneous, isotropic solid materials were derived by the methods of mathematical physics during the 19th century. The physical properties which enter into the relationships ordinarily are density, modulus of E, and Poisson's ratio.

Keywords: concrete dams; NDT methods; elastic wave propagation; density; modulus of E; Poisson's ratio.

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167. PRONYAKIN, V.T. et al., "A half-way flaw detector", Defektoskopiya (the Soviet Journal of Nondestructive Testing), No. 2 (March/April), 1977, pp. 1 - 6; Izdatelstvo Akademii Nauk, Moscow, USSR. (in Russian).

A flaw detector for the inspection of thin-walled parts is described; its readings are based on the first half-wave of the ultrasonic pulse. Defectograms showing an image of the contour of the defect on electrochemical paper are given, along with the results of metallographic analysis. For ultrasonic flaw detection in thin-walled components Lambda waves are most commonly used.

Keywords: defectogram; half-wave of the ultrasonic pulse; thin-walled components.

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168. TIBOR, J., "Impulse methods for controlling the construction speed of prestressed concrete bridges", Proceedings, ACI Journal, Vol. 64, No. 5, 1967, pp. 240 - 243.

Describes the application of two non-destructive impulse methods, viz., the ultrasonic and the sonic hammer methods for checking the quality of concrete. Compares the two methods and gives their advantages and disadvantages especially in relation to speeding up the construction of prestressed concrete bridges.

Keywords: structures; compr. strength; concrete modulus of E; NDT; quality control; sonic testing; ultrasonic testing.

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169. WESCHE, K., "Die Prüfung der Betonfestigkeit im Bauwerk" (Testing the strength of concrete in the structure), Beton-stein-Zeitung, Vol. 33 (5) 1967, pp. 267 - 277.

For ND testing of concrete in the structure besides the ultrasonic test, two by the German DIN 4240 standardized hardness methods can be taken into consideration. However, the bases of these two tests, the ball-impact indentation and the rebound hammer tests, require a thorough technological knowledge of concrete; aggregate gradation, cement paste content, age of concrete, humidity, may result in considerable differences. For hardness methods not only surface characteristics should be considered, but also drying conditions, carbonation depth, type of cement, forming method and segregation are of further considerable influence.

Keywords: NDT of concrete; surface hardness methods; rebound hammer; ball indentation test; ultrasonic pulse velocity; variables.

1968

170. BOROVIKOV, A.S., "Ultraviolet illumination in luminescent nondestructive testing"; Defektoskopiya (The Soviet Journal of Nondestructive Testing), No. 6 (Nov./Dec.), 1968, pp. 70 - 77; Izdatelstvo Akademii Nauk, Moscow, USSR. (in Russian).

The outlook for improving and perfecting luminescent techniques in nondestructive testing by increasing the intensity of ultraviolet excitation is reviewed. Ways of using visible light as the radiation exciting luminescence are discussed. Ultraviolet dosimetric equipment and standards are reviewed. For lack of special equipment, fairly frequent use is made of medical UV irradiation designed for physiotherapy in non-destructive inspection and in luminescent analysis.

Keywords: luminescent N-D testing; closed-circuit; medical UV irradiation; organic phosphors; UV laser; visual-light spotlights; UV irradiation.

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171. HAVERCROFT, W.E., "Nondestructive testing in Canadian governmental services". ASME, Material Technology - Inter-American Approach, May 1968, pp. 254 - 259.

Growth of nondestructive testing in Canada; recognition of this important test method by Canadian Government departments. This will be accomplished by the Government's use of nondestructive testing as an inspection tool for various materials and applications, by its use in research and development and by

education and training problems established for NDT personnel. Programs for certification of industrial radiographers in Canada and radiation safety controls is discussed.

Keywords: NDT; industrial inspection; radiation safety; personnel certification; education and training.

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172. MALHOTRA, V.M., "Testing of concrete by non-destructive methods", The Engineering Journal, Vol. 51, No. 8, August 1968 (EIC - 68 - CIV 8).

At the present time standard methods for testing hardened concrete consist of testing concrete specimens in tension, flexure, and compression. There is delay in obtaining test results; test specimens may not be truly representative of the concrete in structure; specimens have to be stressed to failure; and tests are relatively costly. There are a large number of attempts to develop quick, inexpensive and non-destructive methods for testing concrete both in the laboratory and in the structure. Various NDT methods have been developed which are classified as follows: 1) Surface hardness test; 2) Dynamic tests; 3) Radioactive methods.

Keywords: concrete strength; NDT methods; dynamic methods; resonant frequency; sonic pulse velocity; radioactive methods; gamma radiography.

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173. MALHOTRA, V.M., "Non-destructive method for testing concrete", Mines Branch Monograph 875, Dept. EMR, Ottawa, 1968 (reprinted 1971), 66 pp.

This monograph deals with nondestructive methods for testing concrete. The tests considered are based on (1) surface hardness, (2) dynamic, and (3) radioactive methods. Surface hardness tests

include indentation methods: Williams testing pistol, Frank spring hammer and Einbeck Pendulum hammer. Rebound method describes use of the Schmidt test hammer. Dynamic methods include resonant frequency and ultrasonic pulse velocity methods. Radioactive methods include gamma- and X-ray radiography and back-scatter method for determining the density of concrete layers.

Keywords: density; dynamic tests; gamma radiography; hardness; indentation tests; pulse velocity tests; rebound hammer; resonant frequency test; radioactive test methods; ultrasonic pulse velocity.

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174. MULLINS, L., "The development of nondestructive testing". The Mehl Honor Lecture; Materials Evaluation, Vol. 24, No. 6, June 1968, pp. 93 - 105.

This lecture provides several definitions for the term Nondestructive Testing. The list of tests involved as defined in the terms of reference of the International Committee for Nondestructive Testing reads as follows: a) Radiography and fluoroscopy by X-ray, gamma-ray and neutrons; b) X-ray diffraction; c) Electron diffraction; d) X-ray spectroscopy; e) Ultrasonic methods; f) Eddy current methods; g) Electrical and thermal conductivity tests; h) The use of surface penetrants; i) The use of magnetic tests.

Keywords: NDT methods; definitions; NDT organizations.

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175. PREISS, K., "Checking of cast-in-place concrete piles by radioisotope methods". The Negev Institute for Arid Zone Research, Beer-Sheva, Israel; Report No. 27, July 1968, 12 pp.

This report describes the use of gamma ray transmission and neutron back-scattering methods to check that the concrete is correctly cast. The gamma-ray transmission method is usually preferred, and the effects of various parameters on the accuracy of this method are evaluated.

Keywords: concrete piles; gamma-ray test; neutron back-scattering; radioisotope methods; NDT methods.

1969

176. BRIDGES, W.H, and McCLUNG, R.W., "Computerized Information retrieval - for non-destructive testers a nondestructive memory". Materials Evaluation, Sept. 1969, pp. 199 - 204.

An information centre was formed at the Oak Ridge National Laboratory to store and allow systematic retrieval of the rapidly growing literature on the subject of nuclear fuel technology. Since all methods of nondestructive testing (NDT) are applicable to the technology, much of the NDT literature is within the scope of the information centre. Bibliographic information and abstracts entered into a large computer together with appropriate keywords may be manipulated to recall anything of information on a very specific question. The types of retrieval are discussed.

Keywords: NDT; edge-notched retrieval card; FACSI; concrete strength; ultrasonic pulse velocity; elastic properties.

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177. BRUNARSKI, L. "Recommendations for the use of resonance methods for testing concrete". RILEM Techn. Comm. on NDT of Concrete, meeting at Varna, Bulgaria, Sept. 3 - 6, 1968; RILEM Bulletin Vol. 2, No. 10, 1969.

These recommendations were accepted at the RILEM N-D testing working group meeting held at Varna, Sept. 1968. The following parameters are discussed: a) apparatus characteristics; b) shape, dimensions, curing conditions, specimen age; c) support conditions; d) positioning of driver and pick-up of vibrations; e) calculations formula for dynamic modulus of elasticity; f) symbols and units in SI and MKFS, systems.

Keywords: concrete properties; density; elasticity constants; fundamental resonant; frequency; flexural, longitudinal, torsional.

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178. CEMENT RESEARCH INSTITUTE OF INDIA, "Non-destructive methods of testing concrete". A Review Report RR-2, December 1969, New Delhi, India, 119 pp. (incl. Bibliography, pp. 58 -119, from year 1889 to 1967, a total of 682 entries.

In the non-destructive methods of testing, assessment of some of the properties of the material is made directly, others indirectly. Compressive strength, the most important property of concrete, is assessed indirectly by measuring a property correlated to strength. Concrete increases in strength with hardening, thus the surface hardness test is one NDT technique. A vibration method provides natural frequency of a specimen and thus elastic constants are available. Other methods, for density determination, are the velocity of ultrasonic pulse and the absorption of gamma-radiation.

Keywords: NDT methods; surface hardness; method; indentation method; rebound method; resonant frequency method; dynamic method; vibration method; pulse or wave velocity method; radioactive method; covermeter.

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179. DUNEGAN, H.L. and HARRIS, D., "Acoustic emission - a new nondestructive testing tool", Ultrasonics, Vol. 7, No. 3, July 1969.

A new approach to nondestructive testing is proposed which is centred around the concept of utilizing the transducer action of a flaw in a stress field. This situation results in local plastic deformation occurring in the vicinity of the flaw which in turn gives up energy in several different ways. Thermal emission, exo-electron emission and acoustic emission are the three primary forms that the energy takes upon release. This report is devoted to the subject of acoustic emission.

Keywords: acoustic emission; thermal emission; flaws in the structure; elastic stress field; plastic deformation; stress intensity factor; electro emission.

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180. IDDINGS, F.A. and ARMAN, A., "Application of activation analysis to determination of cement in concrete", Modern Trends in Activation Analyses, N.B.S., Washington, D.C. Spec. Publication No. 312, Vol. 1, 1969, pp. 437 - 443.

The engineer must be assured of the composition, mixing, placing and curing of concrete, the strength and attendant qualities of which vary directly with the cement content and uniformity of cement distribution in the mixture. Activation analysis appears to offer the speed, accuracy, ruggedness, and the simplicity of operation necessary to provide the construction engineer with the desired information in the field. This paper describes laboratory and field studies that utilized fast and thermal neutron activation couples with NaI (Ti) and Ge (Li) detectors.

Keywords: activation analysis; cement; concrete mix; neutron activation; calcium determination; fast thermal neutrons.

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181. JAMES, D.W., "Apparatus for determining dynamic modulus of elasticity and internal damping capacity", Materials Evaluation, May 1969, pp. 102 - 106.

Apparatus developed at the Westinghouse Research and Development Centre, Pittsburgh, Penn., is used to investigate the damping mechanism of metals and alloys measures the damping capacity over wide stress, frequency and temperature ranges. The equipment also provides elastic modulus data over corresponding stress, frequency and temperature ranges. Inherent damping of a material reduces the amplitude at which the material vibrates. This equipment measures very small changes in modulus, which corresponds to observable physical and microstructural changes.

Keywords: damping capacity; dynamic modulus of E; vibrations; structural transformation detection; recrystallization and recovery process of materials.

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182. FACAOARU, I., RILEM Technical Committee on Non-Destructive Testing of Concrete, Chairman's Report on meeting at Varna, Bulgaria, Sept, 1968; RILEM Bull, Vol. 2, No. 10, 1969, pp. 253 - 266. (Building Research Institute (INCERC), Bucharest).

The summary of the discussion, based on the 35 papers presented (see Nos. 183, 184, 185) at the meeting, covers the following topics:

a) Resonance methods (5 pap. Nos. 1 to 5)
b) Ultrasonic pulse methods (18 pap. Nos. 6 to 23)
c) Hardness methods (3 papers Nos. 24, 25, 26)
d) Radioactive methods (2 papers Nos. 27 & 28)

e) Combined methods (4 papers Nos. 29 - 32)

f) Papers received after the meeting (3 papers).

Keywords: resonance methods; ultrasonic pulse; superficial hardness; radioactive methods; combined methods.

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183. RILEM Technical Committee on NDT of Concrete, meeting at Varna, Bulgaria, Sept. 2 - 6, 1968, RILEM Bulletin Vol. 2, No. 10, 1969, 267 pp.

Part A - Papers Nos. 1 to 5.

Resonance methods

1) JONES, R. and WELCH, G.B., "The damping properties of plain concrete".
2) KOTTAS, H., "Über Verfahren zur Bestimmung des dynamischen E und G Modulus.
3) GATEFIELD, E.N., "A method of studying the effect of vibratory stress, including fatigue on concrete in flexure".
4) PAQUET, J., "Etude vibratoire des pieux en béton, réponse harmonique et impulsionnelle. Application au contrôle".
5) BRUNARSKI, L., "Recommendations for the use of resonance methods for testing concrete".

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184. RILEM Technical Committee on NDT of Concrete, meeting at Varna, Bulgaria, Sept. 2 - 6, 1968. RILEM Bull. Vol.2, No. 10, 1969, 267 pp.

Part B - papers Nos. 6 to 23.

Ultrasonic Pulse methods

6) JONES, R., FACAOARU, I. and GATEFIELD, E.N., "A comparison of two techniques for measuring the transit time of an ultrasonic pulse through concrete".
7) MOMMENS, A., "Measures comparatives entre laboratories".

8) FACAOARU, I., "Certain problems of ultrasonic pulse propagation through concrete".

9) MARTINCEK, G., "L'influence du nombre de dimensions du milieu pour les assais dynamique d'impulsion".

10) POPOV, A., "Détermination du module d'élasticité et du coefficient de Poisson pour les granits de diverses qualités a l'aide des ultrasons".

11) FACAOARU, I. and STAMATE, G., "The correlation between the static and dynamic constants of concrete".

12) BAILIEV, G., "An attempt to apply the ultrasonic method to the modelling of civil engineering structures and constructions".

13) REIDING, F.J. "A portable concrete tester".

14) FREIESLEBEN-HANSEN, P., JESSING, I., MONSTED, K. and TRUDSO, E., "Physical and chemical properties of cement mortar cured at elevated temperatures".

15) GALAN, A., "Structural changes in concrete subjected to uniaxial tension established by the ultrasonic pulse methods.

16) ELEVERY, R.C., "Strength of reinforced concrete beams in relation to ultrasonic pulse measurements".

17) TEODORU, G., "Influence of hydro-thermal treatment applied to concrete on the correlation between longitudinal pulse velocity and compressive strength".

18) MOMMENS, A., "Influence du traitement a la vapeur et des conditions de conservation apres le traitement".

19) PETKOV, V., "An investigation on the effect of some factors on the relationship between the strength of concrete and the ultrasonic pulse velocity:.

20) MANGEL, S., "Beitrag zur Beurteilung der gefügegestörten Betone".

21) TEODORU, G., "Statistical assessment of the quality of precast concrete by ultrasonic pulse methods and by superficial hardness methods".

22) JONES, R. and FACAOARU, I., "An analysis of the answers to a questionnaire on the ultrasonic pulse method for testing concrete".

23) JONES, R. and FACAOARU, I., "Recommendations for testing concrete by ultrasonic pulse method".

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185. RILEM Technical Committee on NDT of Concrete, meeting at Varna, Bulgaria, Sept. 2 - 6, 1968. RILEM Bulletin Vol. 2, No. 10, 1969, 267 pp.

Part C, D & E - papers Nos. 24 - 32.

Hardness, Radioactive and Combined methods

24) WESCHE, K. and MANGEL, S., "Beitrag zur Beurteilung der Festigkeitsverteilung des Betons in Bauwerken".

25) PETROV, L.K., "On the accuracy of the non-destructive testing of concrete".

26) KOLEK, J., "Draft recommendations for the use of hardness methods in the non-destructive testing of concrete".

27) PREISS, K., "Checking of cast in place concrete piles by radioisotope methods".

28) POHL, E., "Design of a standard for determining the density in large concrete structural units".

29) WIEBENGA, J.A., "A comparison between various combined non-destructive testing methods to derive the compressive strength of concrete".

30) FACAOARU, I., DUMITRESCU, I. and STAMATE, G., "New developments and experience in applying combined non-destructive methods for testing concrete".

31) GALAN, A., "A two-parameter dynamic pulse method for the determination of the concrete strength in direct tension and optimum time for specimen testing".

32) STEFANESCU-GOANGA, A., "Sur l'emploi des méthodes d'essai non-destructives roumaines au contrôle de la qualité du béton".

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186. JONES, R. and FACAOARU, I., "Recommendations for testing concrete by ultrasonic pulse method". RILEM Techn. Comm. on NDT of concrete, meeting at Varna, Bulgaria, Sept. 2 - 6, 1968, RILEM Bulletin Vol. 2, No. 10, 1969.

These recommendations deal with the application of the ultrasonic pulse method to derive the elastic properties, strength and homogeneity of structural concrete, and for locating internal defects, etc. Methods are recommended for overcoming difficulties associated with the dedication of elastic properties and strength from in-situ measurements of pulse velocity.

Keywords: compressive strength; cracking; defects in concrete; defectoscopy; dynamic modulus of elasticity; homogeneity of concrete; Poisson's ratio; pulse velocity; non-destructive testing; path length; transducers; transit time.

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187. KOLEK, J., "Analysis of answers to RILEM questionnaire on the Schmidt rebound hammer", RILEM Technical Commission NDT of Concrete, meeting at Varna (Bulgaria), Sept. 2 - 6, 1968, publ. RILEM Bulletin Vol. 2, No. 10. 1969.

At the RILEM NDT Comm. meeting in Bucharest, Sept. 1964 it was decided that a questionnaire be circulated on the Schmidt rebound hammer. The purpose was to establish a consensus of informed opinion on a) the circumstances of use and expected accuracy of prediction of concrete quality and b) the method of use and interpretation of results. The RILEM secretariat circulated the

questions and 57 replies were subsequently received, covering 28 countries.

Keywords: concrete compressive strength; concrete hardness test; calibration; rebound hammer; Schmidt impact hammer.

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188. KOLEK, J., "Recommendations for the use for surface hardness methods in the non-destructive testing of concrete". RILEM Techn. Comm. on NDT of Concrete, meeting at Varna, Bulgaria, Sept. 2 - 6, 1968; RILEM Bulletin Vol. 2, No. 10, 1969.

These recommendations cover two types of hardness testers: a) rebound testers and b) indentation testers. Usages are:

1) Checking the uniformity of concrete quality in terms of hardness;
2) Approximate estimation of strength in terms correlated with hardness index;
3) Comparing given concrete with reference in terms of a specific requirement.

Paper discusses factors influencing the test results, and describes methods of testing a structure and calibration of testing devices.

Keywords: compressive strength; surface hardness; indentation testers; calibration curves; rebound tester.

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189. LANGE, Yu.V., "Phase version of the acoustic-impedance method of nondestructive testing", Defektoskopiya (the Soviet Journal of Nondestructive Testing), No. 3, (May/June) 1969, pp. 1 - 2, Izdatelstvo Akademii Nauk, Moscow, USSR (in Russian).

The acoustic-impedance method, used for the non-destructive testing of the joints in multilayer structures, is described. The mechanical impedance of the object being tested is evaluated from the amplitude of the object's reaction force to the vibrations excited in it by the transducer. This method is adopted in the type IAD-2 test apparatus.

Keywords: acoustic-impedance method; mechanical impedance method; frequency m.; phase m.; amplitude m.; multilayer structure testing; IAD-2 test apparatus.

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190. LEERS, K.J. "Die zerstörungsfreie Materialprüfung mit mechanischen schwingungen und ihre Anwendung bei Werkstoffer der Steins und Erden-Industrie" (Use of mechanical vibrations for non-destructive testing of materials and its application in the building materials industry). Ph.D. Thesis at the Techn. University Clausthal; a booklet, Nov. 1969, 222 pp., 197 ref.

Basic principles of mechanical vibrations and types of waves; effect of materials elastic parameters on wave velocity; modulus of elasticity; E, Poisson's ratio; density of material; resonant frequency and pulse velocity; compressive strength determination; different ultrasonic testing equipment.

Keywords: NDT; compressive strength; density; elastic properties; type of sonic waves; ultrasonic pulse velocity.

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191. SAUNDERS, G.A. "Pulse echo ultrasonics", Engineering Ltd., Engineering Outline 203, Nov. 21, 1969 (Univ. of Durham).

The pulse echo technique consists of the measurement of the absorption and transit time of an ultrasonic wave packet as it is

propagated through a material and undergoes multiple reflections at interfaces with substances of different acoustical properties. The velocity of sound depends directly upon sample density and elasticity.

Keywords: elasticity; materials testing; sonic waves; sound propagation; transit time; pulse velocity; ultrasonic testing.

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192. WESCHE, K. und MANGEL, S. "Beitrag zur Beurteilung der festigkeitsverteilung des betons in Bauwerken" (Contribution to the evaluation of concrete strength distribution in a structure), Beton, Vol. 19 (3), 1969, pp. 107 - 111.

In order to evaluate compr. strength of concrete in a structure by using one or two ND test methods, a destructive compressive strength test on a core is needed to correlate the ND test results with actual compr. strength in certain parts of a structure. The obtained relationships are valid only for a limited part of a building, and cannot be used for strength estimation in other parts of the same building.

Keywords: compr. strength of concrete; ND hardness test methods; ball-impact indentation; rebound test hammer; drilled test core; strength correlation curve.

1970

193. BRITISH STANDARDS INSTITUTION, "Recommendations for nondestructive methods of test for concrete - Gamma radiography of concrete", BS 4408, Part 3, 1970.

The increased use of gamma rays for the location and identification of steel and voids in structural concrete has made it desirable to issue some recommendations of a general character giving guidance on the procedures at present being used.

Keywords: NDT; dose rate meter; Gamma-ray; sources; image; lead screen; radiographic techniques; scattered radiation; X-ray film.

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194. BROWN, B.R. and KELLY, R.T., "Practical applications of non-destructive testing techniques for concrete". Symposium on NDT of Concrete & Timber (Session D), June 11 - 12, 1969; Inst. Civil Engrs., London, England, 1970, pp. 67 - 75.

Since NDT methods are used on hardened concrete, they are unsuitable for concrete quality control during construction work, because the results are subject to delay. They can be used for appraisal of design and trouble shooting after completion of the work. For the site quality control a good test method is a rapid analysis of trash concrete, by which a sample can be determined in 10 - 15 min.

Keywords: NDT methods; cube strength; chemical analysis; concrete mix quality control; covermeter measurements; radiographic techniques; vibration techniques; ultrasonic testing; surface hardness tests; permeability tests.

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195. ELVERY, R.H. and DIN, N.M. "Ultrasonic inspection of reinforced concrete flexural members". Symposium on NDT of Concrete & Timber (Session C), June 11 - 12, 1969; Proceedings, Inst. Civ. Engrs. London, 1970, pp. 51 - 65.

The paper describes an investigation which has examined the use of pulse velocity measurements for predicting the structural

performance of reinforced concrete beams. The results of pulse velocity tests show a better correlation with the flexural strength of reinforced concrete beams than that indicated by cube tests.

Keywords: concrete strength; flexural strength; pulse velocity; reinforced concrete; shear strength; ultrasonic tests.

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196. ELVERY, R.H. "Developments in the ultrasonic testing of concrete". Presented at 3rd Annual Convention of the Concrete Society, Nottingham; Concrete, Vol. 4, No. 6, 1970, 223 pp.

Introduced the subject of NDT of concrete and indicated that some of the objections to ultrasonic testing were overcome. Advances in electronic components have led to development of smaller, fully portable equipment for in-situ use. Equipment with digital display output has been developed at the University College, London, known as PUNDIT (Portable Ultrasonic ND Digital Indicating Tester). It enables pulse velocity to be measured in concrete of 30 ft or more in thickness to an accuracy $\pm$ 2%. Ref.:

1) C.N.S. Instruments Ltd, 61 - 63, Holmes Rd., London, NW5 3AN.
2) "Pundit sets the pace", The Consulting Engineer, July 1970.
3) "Concrete testing", The Consulting Engineer, September, 1970.

Keywords: NDT; ultrasonic pulse velocity; elasticity m.; PUNDIT; compr. strength of concrete; correlation curves; concrete quality.

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197. FILIMONOV, S.A. and ERMOLOV, I.N., "Theory of the resonance inspection method, I", Defektoskopiya (the Soviet Journal of Nondestructive Testing), No. 5, Sept./Oct., 1970, pp. 9 - 16, Izdatelstvo Akademii Nauk, Moscow, USSR (in Russian).

The resonance method of inspection is based on exciting ultrasonic vibrations in the acoustic circuit and recording resonance phenomena in it at certain (resonant) frequencies. In this case the acoustic circuit is an acoustic oscillatory system. The more pronounced the resonance phenomena in it, the easier it is to detect them and the simpler it is to process the information obtained.

Keywords: electro-acoustic circuit; resonance inspection; acoustic probe-damper, piezoelectric plate and protector.

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198. FORRESTER, J.A. "Gamma radiography of concrete". Symposium on NDT of concrete & Timber (Session B), June 1969; Proceedings, the Institute of Civil Engrs., London, 1970, pp. 13 - 17.

The principles, techniques and limitations of gamma radiography of concrete are reviewed. They are discussed with references to that part of the proposed British Standard Recommendations for NDT of concrete which deals with gamma radiography. The engineering and radiographical considerations of the technique are discussed, and examples of the use of radiography are given.

Keywords: gamma rays; radioactive isotopes; radiation attenuation; radiography.

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199. IREDALE, P. "Neutron radiography", Engineering Ltd., Engineering Outline 232, UDC 620.179.1, pp. 615 - 618.

Neutron radiography is the use of a beam of neutrons to penetrate an object and produce an image revealing the internal details. The resulting pictures are similar to the more familiar X-radiographs.

In principle the only difference between the two methods of radiography is the type of radiation used.

Keywords: NDT; neutron radiography; radiation; radioactive isotopes; neutron generator.

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200. JONES, R. "A review of the non-destructive testing of concrete". Symposium on NDT of Concrete & Timber (Session A), June 11 - 12, 1969; Proceedings, Inst. of Civil Engrs., London, 1970, pp. 1 - 12.

A review of NDT techniques for measuring or deriving the properties of concrete which determine its structural behaviour. The methods considered are:

a) vibrational method for estimating strength, studying homogeneity and durability;
b) radioactive methods for measuring density, moisture content, and locating reinforcement;
c) hardness methods for estimating strength;
d) electrical methods for measuring moisture content;
e) magnetic methods for measuring depth of cover over reinforcement steel.

Keywords: concrete; density; durability; electrical method; magnetic methods; moisture content; radioactive methods; vibrational methods.

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201. KOLEK, J. "Non-destructive testing of concrete by hardness methods". Symposium on NDT of Concrete & Timber (Session B), June 11 - 12, 1969; Proceedings, Inst. Civil Eng., London, 1970, pp. 19 - 22.

There are basically two methods: the rebound method and the indentation method. Both are well known, but detailed meaningful interpretation of results is often not easy and can be burdened with uncertainty. A great number of readings can be taken easily at little expense and the corresponding improvement in confidence of a given level of quality is an aspect of these methods that is largely under-appreciated. Many factors influence the results.

Keywords: concrete strength; hardness; indentation test; rebound test; calibration of the instrument.

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202. LEVITT, M. "Non-destructive testing of concrete by the initial surface absorption method". Symposium on NDT of Concrete & Timber (Session B), June 11 - 12, 1969; Proceedings, Inst. Civil Engrs., London, 1970, pp. 23 - 26.

The paper describes the mechanism involved in water penetrating concrete and also shows how one can interpret the results obtained in term of resistance to frost and chemical attack, colour change and lime bloom efflorescence. The durability requirements for roofing tiles are covered by a permeability test, which is referred to in this text as the initial surface absorption test (ISAT).

Keywords: absorption; chemical attack; frost attack; durability; efflorescence; colour change; moisture movement; permeability; initial surface absorption.

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203. LIPNIK, V.G. and FILONIDOV, A.M., "Investigation of the discernibility of flaws in concrete by ultrasound", USSR Orgénergostroi Institute; Defektoskopiya, No. 5, pp. 3 -9, Sept./Oct. 1970 (in Russian).

The conditions under which an ultrasonic pulse propagates around or near a flaw in concrete are discussed. Results of ultrasonic flaw detection techniques, in ultrasonic transmission through standard concrete specimens, are presented. Relations between flaw diam., the length of the travelling wave, and the pulse characteristics are calculated and an alignment chart is constructed as an aid in determining the dimensions of the flaws.

Keywords: concrete cracks; flaws; calibration chart; ultrasonic pulse velocity.

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204. MALHOTRA, V.M., "Preliminary evaluation of Windsor probe equipment for estimating the compressive strength of concrete", Mines Branch Report IR 71-1, Dept. of Energy, Mines and Resources, Ottawa, Canada, December 1970.

There is some degree of correlation between compressive strength of concrete and the exposed length of Windsor probe. However, because of large variability in the probe test results, the usefulness of this test lies in determining the relative quality of concrete in place rather than in its use for predicting the compressive strength of concrete. Because of damage to concrete this test is more useful for massive concrete sections, e.g., bridge abutments, foundations, etc.

Keywords: compressive strength; concrete hardness; ballistic probe; Windsor probe test; penetration test.

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205. MALHOTRA, V.M. and BERWANGER, C., "Correlations of age and strength with values obtained by dynamic tests on concrete", Mines Branch Report IR 70-40, Dept. of Energy, Mines and Resources, Ottawa, Canada, June, 1970.

Compressive strength, dynamic modulus of elasticity, and pulse velocity increase with age, being greatest for compressive strength and least for pulse velocity. The correlation between dynamic modulus of E and the 28-day compressive strength of concrete is significant with a correlation coefficient of 0.70. The correlation between the dynamic modulus E and the 28-d. flexural strength is curvilinear. Correlation between compressive strength and pulse velocity is poor.

Keywords: concrete; compressive strength; dynamic modulus of E; flexural strength; pulse velocity; age of concrete; dynamic tests of concrete.

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206. POLLOCK, A.A. "Acoustic emission", Engineering Ltd., Engineering Outline 232, UDC 534. 2, 1970, pp. 639 - 642.

Acoustic emissions (AE) are elastic waves produced by deformation in stressed materials. They carry part of the elastic energy released during deformation. Many kinds of deformation yield detectable emission. Emissions are detected by an ultrasonic transducer or accelerometer which converts the stress wave into an electrical signal, shown on the oscilloscope.

Keywords: NDT; failure prediction; Kaiser effect; mechanical signature analysis; stress wave emissions; ultrasonic testing.

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207. REHM, G., WAUBKE, N.V., NEISECKE, J., "Ultraschall Untersuchungsmethoden in der Baupraxis, Abschlussbericht" (Ultrasonic test methods in construction practice). A literature review for the Technical University, Braunschweig, Germany, July 14, 1970, 59 pp.

This is a research contract sponsored by Federal Ministry for Housing and City Development, in W. Germany (Az.; II A6 - 80 01 67 - 12). The work covers:

a) personal interviews with about 30 German and foreign experts in the field of NDT methods for concrete;
b) scanning over 35 international trade magazines, covering construction and materials testing fields;
c) evaluation of Proceedings from about 10 international conferences and seminars related to NDT of concrete.

This report contains 218 ref. of published papers and books on ultrasonic NDT methods, in German, English and French.

Keywords: references on NDT of concrete.

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208. SHAH, S.P. and CHANDRA, S. "Mechanical behaviour of concrete examined by ultrasonic measurements", ASTM, Journal of Materials, Vol. 5, Sept. 1970, pp. 550 - 563.

Ultrasonic measurements provide an external and continuous indication of internal microcracking. The cyclic and sustained loading of concrete results in two stages of slow crack growth: Stage 1 involves slow rate of cracking in the non-failed specimens; Stage 2 crack growth is associated with failure, sharp increase in attenuation and sharp decrease in velocity of the pulse.

Keywords: concrete; cyclic loading; microcracking; pulse velocity; pulse attenuation.

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209. ZIMMER, U. and RUMPF, W. "Anwendungsmöglichkeiten eines Kleinst-Ultrashallgerätes in der Baupraxis" (Application possibilities of a mini-ultrasonic detector in construction practice); Betonstein-Zeitung, Heft 2, 1970, pp. 124 - 126.

A description is given of the essential testing methods for routine applications by means of the ultrasonic test, which are to be carried out with a mini ultrasonic detector designed for field uses. Outlined are also the limits of these testing methods. Complicated or scientific testing methods have not been mentioned, on purpose, as the use of this equipment in the field will be carried out by auxiliary personnel.

Keywords: NDT; compressive strength; correlation curve; combined methods; Schmidt test hammer; ultrasonic pulse velocity; crack detection.

1971

210. ASTM, "Standard Method of Test for Pulse Velocity Through Concrete", Book of ASTM Standards, Designation C 597-71. This Standard first appeared in the 1967 Book of ASTM Standards, Part 10, as a Tentative.

This method covers the determination of the pulse velocity of propagation of compressional waves in concrete, for the purpose of determining the condition of the concrete comparatively. It may be used to assess the uniformity of field concrete, to indicate changes in characteristics in concrete, and in the survey of field structures to estimate the severity of deterioration, cracking, or both. The results obtained should not be considered as a means of measuring strength of concrete. The procedure is applicable in both field and laboratory testing regardless of size or shape of the specimen.

Keywords: concrete; cathod-ray oscilloscope; compressional waves; cracks; deterioration of concrete; pulse velocity; pulse generation; transducers; traveltime; ultrasonic pulse velocity.

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211. BRITISH STANDARDS INSTITUTION, "Recommendation for non-destructive methods of test for concrete - Surface hardness methods", BS 4408, Part 4; 1971.

The methods provide only an approximate indication of quality but they may be useful in a number of applications. No single correlation with strength or other measurable property of concrete is generally applicable, and calibration under a specific set of circumstances is necessary if acceptable accuracy is to be obtained. These recommendations provide guidance for two types of concrete hardness tests: (1) rebound hammers, and (2) indentation testers.

Keywords: NDT; calibration; concrete strength; hardness; indentation; imperfection in concrete; quality control; uniformity of concrete.

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212. BHARGAVA, J. "Application of some nuclear and radiographic methods on concrete", RILEM Bull. No. 22, July/Aug., 1971, pp. 231 - 238.

Gamma-ray transmission method was used for studying the variations in density of concrete caused by settling in columns. Moisture content of concrete was determined by the neutron scattering technique, and distribution of cement by radioactive tracer analysis. The structure of concrete was studied by radiographing thin slices of concrete. Formation and propagation of cracks was studied from radiographs taken at regular intervals.

Keywords: cracks in concrete; gamma-ray transmission; moisture content; density of concrete; neutron scattering; radioactive tracer; radiographs.

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213. CAPATU, C. et DIACONU, D. "Une méthode dynamique de détermination des caractéristiques de l'ancrage des armatures dans le béton" (A dynamic method to determine bond characteristics of reinforcement in concrete), RILEM Bulletin No. 23, Sept./Oct. 1971, pp. 305 - 312.

La méthode presentée ci-dessous est destinée a contribuer au perfectionnement des déterminations qui peuvent être effectuées à l'aide de l'essai d'arrachement (pull-out test). Il a été établi qu'il existe une relation étroite entre l'affaiblissement de l'adhérance et les variations des grandeurs dynamiques analyses, la frequence et le pourcentage d'amortissement critique.

Keywords: anchorage; concrete strength; bond strength; pull-out test.

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214. DSENIS, V.V. and LAPSA, V.Ch., "Ultrasonic control of cement hardening", Stroiizdat, Leningrad, 110 pp. 1971. (book in Russian).

This book deals with: cement hardening under natural and elevated or low temperatures; investigation of concrete hardening by use of acoustic methods; the relation between pulse velocity, modulus of elasticity and Poisson's ratio for isotropic and monotropic materials; and the correlation between compressive strength of concrete and velocity of sound in hardened concrete.

Keywords: concrete compressive strength; acoustical waves; pulse velocity; modulus of elasticity; hardening of cement paste; N-D testing for strength of concrete.

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215. ELVERY, R.H. and FORRESTER, J.A., "Non-destructive testing of concrete". A chapter from the book "Progress in Construction Science and Technology", Medical and Technical Publishing Co. Ltd., Aylesbury, U.K., 1971, pp. 175 - 216.

Content:

6.2 - The need for testing concrete non-destructively
6.3 - Application of non-destructive testing
6.4 - The availability of NDT techniques
6.5 - Vibration methods
6.6 - Radioactive techniques in NDT of concrete
6.7 - Surface methods
6.8 - Electrical methods
6.9 - Implications of non-destructive test results.

Keywords: concrete strength; dynamic modulus of E; density; durability; dielectric constant; impact tests; isotopes; electromagnetic tests; gamma backscatter; nuclear radiation; radiography; rebound hammer; resonant frequency; sonic tests; ultrasonic pulse; vibration methods.

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216. ELVERY, R.H., "Non-destructive testing of concrete and its relationship to specifications", Concrete Journal of the Concrete Society, Vol. 5, No. 4, May 1971, pp. 137 - 141.

Some of the NDT methods are already incorporated in British Standards and Recommendations, and further methods are likely to be added to these very soon. In order to appreciate the role of NDT in specifications it is necessary to consider the essential purpose

of testing and, in particular, compliance testing. Some NDT methods are suitable for checking concretes at various stages of its manufacture and others for assessing the quality of the end product. This article suggests lines of approach for incorporating these methods in future specifications.

Keywords: NDT methods; British Standards and Recommendations; compliance testing; acceptance testing.

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217. GREEN, A.T., "Stress wave emission and fracture of prestressed concrete reactor vessel materials". Dunegan Research Corp., Livermore, Cal., Techn. Report DRC -71-3, May 1971.

The stress-wave emission (SWE) detect the failure and progression of failure in cylindrical concrete specimens and a model prestressed concrete pressure vessel. Emission data have provided a description of the time relationship between the onset and continuing failure process. Findings of the study have shown that variations in the stress-wave emission data can determine impending failure and previous structural loading extremes.

Keywords: stress-wave emission; concrete failure; stress-wave sensors; crack initiation; plastic deformation.

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218. JONES, R., RILEM working group on non-destructive testing of concrete: meeting held at Wexham Springs, Slough, U.K., June 23-26, 1970. Chairman's report, RILEM Bull. Vol. 4, No. 19, 1971, pp. 58/59.

At the meeting were presented and discussed 31 papers covering the following topics.

a) Resonance method (4 papers);

b) Ultrasonic pulse method (9 papers);

c) Superficial hardness method (4 papers);
d) Combined method (1 paper);
e) Surface wave method (1 paper);
f) Radiographic method (2 papers);
g) Radiometric method (5 papers).

Keywords: resonance method; ultrasonic pulse velocity; superficial hardness; surface wave; radiographic method; radiometric method.

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219. KLOTZ, R.C., "Field investigation of concrete quality using the Windsor Probe test system". Paper presented at the 50th Annual Meeting of the NRB, Washington, D.C., Feb. 1971, 49 pp.

Investigations have been made of in-place compressive strength and concrete quality determination using Windsor probe test system. A steel probe is driven into concrete with a constant energy and the depth of probe penetration used as a measure of resistance to penetration, indicating the compressive strength of concrete.

Keywords: concrete; compressive strength; depth gage; exposed length of probe; power driver; penetration depth; in-place testing; Windsor Probe test system.

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220. LEPPER, H.A., Jr. and RODGERS, R.B., "Nuclear methods for determining the water content and unit weight of fresh concrete", Journal of Materials, JMLSA, Vol. 6, No. 4, Dec. 1971, pp. 820 - 841.

The use of nuclear radiation to determine the water content and unit weight of aggregates and freshly mixed concrete was studied. Neutron radiation was used to determine the quantity of water present in samples of standard shape and size. Gamma radiation was

used to measure unit weights of samples of sand, gravel, cement, and concrete of the same dimensions.

Keywords: concrete; aggregates; gravel; sand; portland cement; nuclear radiation; gamma rays; neutron irradiation; thermal neutrons; moisture content; density (mass/volume).

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221. MacLEOD, G., "An assessment of two non-destructive techniques as a means of examining the quality and variability of concrete in structures", Cement and Concrete Association, Technical Report 42. 454, July 1971, 26 pp.

The results of two series of tests are presented as a first stage of the assessment of the partial safety factor, Ym, for concrete strength. The non-destructive techniques of pulse velocity and rebound index were used for predicting the characteristic strength of small concrete columns. It is concluded that a reasonable empirical assessment of Ym by non-destructive techniques is possible. The test results indicate a need for the adoption, in addition to Ym, of a quality acceptance factor, Yp.

Keywords: concrete construction; columns (structural); tests; quality; variability; non-destructive testing; safety factor.

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222. MALHOTRA, V.M. and PAINTER, K., "Evaluation of the Windsor Probe test for estimating compressive strength of concrete", Mines Branch Report IR 71-50, Dept. of Energy, Mines and Resources, Ottawa, Canada, July, 1971.

The Windsor Probe test determines the resistance of hardened concrete to penetration by a ballistic steel probe. It is suitable for determining the relative quality of concrete in much the same way as the Schmidt test hammer. However, its greater usefulness is

in quantitatively predicting the 28-day compressive strength of concrete.

Keywords: driving unit; Windsor probe; self powered apparatus; penetration test.

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223. NUCLEAR - CHICAGO Corp., Austin, Texas, "Pretesting concrete quality by gamma-ray backscattering". A research project sponsored by the Fed. Highway Administration and Atomic Energy Commission; Public Roads, Vol. 36, No. 9, Aug. 1971, pp. 180 - 183.

A portable nuclear gage to determine the cement content of plastic concrete has been developed by the FHA and AEC in USA, espec. for concrete with siliceous aggregate. The type of aggregate has to be classified, and a calibration curve for each is established by radiometric determination.

Keywords: americium (Am^{137}) and cesium (Cs^{137}) isotopes; backscatter; calibration curves; cement content; concrete mixture; gamma-ray backscatter; nuclear gage; radio isotopes; X-ray fluorescence.

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224. POPESCU, N.D. "Zerstörungsfreie Prüfung von Beton mit dem Ultraschallimpulsverfahren" (Non-destructive testing of concrete, using the ultrasonic pulse method), Materialprüfung, Vol. 13, No. 3, March 1971, pp. 85 - 88.

Gives details and blockscheme of the updated equipment "Ultrasoniscop LIN-2". The apparatus consist of 5 parts, one permanent and four exchangeable. To determine effect of different concrete composition, three sets of concrete mixes were prepared as follows: a) 3 diff. W/C ratios; b) 3 diff. aggr. gradings; c) 2

cement amounts (300 & 500 kg/m^3). Compressive strength of cubes at diff. concrete ages were correlated graphically with the ultrasonic pulse velocity, showing good relations between compressive strength and pulse velocity.

Keywords: NDT; composition of concrete mix; variation in W/C; C amount; aggr./cement ratio; changes in ultrasonic pulse velocity.

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225. SWAMY, N. and RIGBY, G., "Dynamic properties of hardened paste, mortar and concrete". RILEM Bulletin No. 19, Jan./Feb. 1971.

The dynamic moduli and the damping properties of hardened paste, mortar matrix and concrete prisms excited in fundamental longitudinal, flexural and torsional vibrations are presented. Relations between dynamic moduli and strength, between damping capacity and compressive strength, and between dynamic moduli and the properties of the constitutes are presented.

Keywords: compressive strength of concrete; damping capacity of concrete; dynamic moduli; dynamic test methods; fundamental resonant frequency; vibrational methods.

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226. TASSIOS, T. and OECONOMOU, Ch., "A contribution to the gamma radiography of reinforced concrete structures", RILEM Bull. No. 20, March/April, 1971, pp. 101 - 105.

New proposals in gamma radiography techniques have been investigated:

a) Photometric measurements on simple gamma-radiographics have been applied, to estimate the diameter of an embedded bar.
b) Ordinary photogrammetric apparatuses have been used to twin stereo-radiographics for direct discrimination of complicated

bars of concrete reinforcements. The same method was applied for a direct reading of the position and diameter of every bar simultaneously, instead of repetitional application.

Keywords: concrete reinforcement; diameter of bars; location of bars; gamma radiography; photometric measurements; photogrammetric readings; stereo radiography.

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227. WAITE, E.V. and PARRY, D.L. "Field evaluation of heavy-walled pressure vessels using acoustic emission analysis", Materials Evaluation, June 1971, pp. 117 - 124.

Idaho Nuclear Corp. has developed a portable acoustic analysis system that detects, locates and analyzes microacoustic energy emission originating from flaws or cracks within a stressed structure. Acoustic emission data were obtained and on-site analyses made of the integrity of several large industrial chemical reactor pressure vessels in conjunction with the hydrostatic acceptance testing of the vessels.

Keywords: acoustic emission; detection of flaws; cracks; stressed structure; NDT; pressure vessels.

1972

228. ARNI, H.T., "Impact and penetration test of portland cement concrete", Federal Highway Administration, Research & Development, Washington, D.C.; Report No. FHWA-RD-73-5, Feb. 1972.

Tests using the Swiss rebound hammer and Windsor probe test system were made on concrete slabs and cylinders. Although both hammer and probe show correlation with compressive strength, neither test

provides a precise determination of concrete strength that can be used to assess relative quality of concrete. The Swiss hammer has an advantage because more tests can be made on a given area, the cost per test is less, and it is nondestructive.

Keywords: ballistic probes; compressive strength of concrete; driving unit; hardness test; impact hammer; calibration curves; rebound test hammer; Schmidt test hammer; Windsor probe; penetration test.

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229. ASTM, "Acoustic Emission", Special Technical Publication No. 505, 1972. (A compilation of 20 papers presented at the Symposium on Acoustic Emission at the ASTM Committee Meeting on Dec. 7-8, 1971 in Bal Harbor, Fla.).

The first section is primarily introductory papers for general understanding of acoustic emission, including historical background and discussions of the relevant aspects of dislocation dynamics, micro-cracking processes, rock mechanics, materials studies and structural evaluation studies. The remaining sections comprise a review of specific research and application areas. The Subcomm. Report on Recommended Acoustic Terminology is appended.

Keywords: acoustics; emission; stress waves; deformation; failure; cracking; elastic waves.

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230. BROWNFIELD, Wm.E., "Non-destructive testing of concrete by wave velocity methods", NRB, Highway Research Record No. 378, 1972.

A seismic velocity technique similar to that employed in geophysical investigations was used and compared with the soniscope method. These elastic wave velocities are influenced in a complex

way by several characteristics of concrete: compressive strength, density, elastic properties, cracks and microcracks, reinforced steel and aggregates. Each elastic wave was generated with a pendulum hammer.

Keywords: compressive strength of concrete; density; elastic properties of concrete; elastic waves; seismic waves; seismic velocity; soniscope; V-scope.

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231. DIN 1048, "Prüfverfahren für Beton, Blatt 2, Bestimmung der Druckfestigkeit von Festbeton fertiger Bauwerke und Bauglieder" (Testing methods for concrete, Part 2: Determination of compressive strength of hardened concrete in buildings and structural parts); Sept. 1972.

This DIN standard is published as a draft offered for discussions and is not the final version. Reference is made to DIN 1045 and DIN 1048, Part 1, publ. Jan. 1972. It covers both the destructive and non-destructive testing methods for determination of compr. strength of concrete in structures and structural parts. Of the NDT methods in this standard only the surface hardness tests are covered. These are the ball indenting spring hammer (type Baumann-Steinrück) and the Schmidt rebound hammer.

Keywords: NDT; ball indentation; rebound hammer; spring hammer; calibration curve.

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232. DUNEGAN, H.L. and GREEN, A.T., "Factors affecting acoustic emission response from materials", ASTM STP 505, 1972, pp. 100 - 113,

This paper discusses the many factors that can influence the acoustic emission response from materials. Hopefully it gives a better understanding of the need for characterization of the acoustic emission response of materials prior to application of the techniques for determination of structural integrity.

Keywords: acoustic detection; acoustic properties; sound transmission; tension tests; mechanical properties; heat treatment; cracking; stresses.

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233. HARDY, H.R., Jr., "Application of acoustic emission techniques to rock mechanics research". ASTM STP 505, 1972, pp. 41 - 43.

This is a comprehensive review of the applications of acoustic emission in the field of rock mechanics. Acoustic emission experiments in rock mechanics were initiated in N. America in the late 1930's as part of a study by the US Bureau of Mines into problems associated with mine design and alleviation of rock bursts. This paper outlines major rock mechanics areas where acoustic emission techniques are being applied and includes a brief description of applied studies.

Keywords: acoustics; emission; sound transmission; microseismics; rock mechanics; acoustic detection; stability; cracks.

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234. INDIAN CONCRETE JOURNAL, Editorial, "Non-destructive testing of concrete - a general appraisal", Indian Concrete Journal, Vol. 46, No. 9, Sept. 1972, pp. 349/50.

Laboratory strength tests of concrete enable the variability of mix constituents to be controlled, but they cannot account for diff. conditions of corresponding concrete placed and cured in a structure. These differences forced provision of non-destructive

methods for testing structural concrete in situ. There are many methods currently used for NDT application: 1) resonance tests; 2) radioactivity method; 3) magnetic methods; 4) Schmidt rebound hammer tests; 5) penetration resistance test; 6) ultrasonic pulse method.

Keywords: combined test methods; gamma radiography; Pundits; radioactivity; magnetic covermeter; resonant frequency; Schmidt test hammer; ultrasonic pulse velocity; Windsor Probe.

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235. LIPTAI, R.B., HARRIS, D.O. and TATRO, C.A. "An introduction to acoustic emission", ASTM Sp. Tech. Publ. 505, 1972.

A brief introduction to the field of acoustic emission is presented. The basic mechanism of acoustic emission, a brief historical survey of the field and some of its applications to materials research and structural integrity evaluation are discussed. Areas of future development also are presented.

Keywords: acoustic detection; acoustic properties; sound waves; stress waves; acoustic measurements; sonic tests.

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236. MALHOTRA, V.M., "Recent developments in test methods and equipment for evaluation of in-situ concrete". Mines Branch Report MPI (A) 72-9, Dept. of Energy, Mines and Resources, Ottawa, Canada, May 1972, pp. 19. (Presented at the 2-Day International Seminar on Concrete Technology, Monterrey, Mexico, Dec. 7/8, 1972).

Under new test methods discussed are: a) Windsor Probe Test and the Pull-Out Test; their advantages and limitations are shown. Under new equipment are described a) "Pundit", the portable ultrasonic concrete tester, and b) Concrete Maturity meter.

Keywords: Windsor Probe; hardness tester; driver; gun; pull-out test; Pundit; ultrasonic velocity; soniscope; maturity meter.

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237. MALHOTRA, V.M., "Windsor Probe test for evaluation of strength of precast concrete". Mines Branch Report MPI (A) 72-10, Dept. of Energy, Mines and Resources, Ottawa, Canada, 1972, 14 pp.

In recent years a number of patents for various pull-out test methods have been registered in different countries. In the USA, Owen Richards has been advocating the use of such test on structural concrete members. The pull-out test measures, with a special tension ram, the force required to pull-out test measures, with a special tension ram, the force required to pull out a specially shaped steel rod whose enlarged end has been cast into concrete. It pulls out a cone of the concrete, to be simultaneously in tension and in shear.

Keywords: compressive strength; concrete; exposed length of probe; penetration depth; power driver; gun.

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238. MALHOTRA, V.M., "Evaluation of the pull-out test to determine strength of in-situ concrete". Mines Branch Investigation Report IR 72-56, Dept. of Energy, Mines and Resources, Ottawa, Canada, Nov. 1972, 29 pp.

In recent years a number of patents for various pull-out test methods have been registered in different countries. In the USA, Owen Richards has been advocating the use of such test on structureal concrete members. The pull-out test measures, with a special tension ram, the force required to pull-out a special tension ram, the force required to pull-out a specially shaped steel rod whose enlarged end has been cast into concrete. It pulls

out a cone of the concrete, to be simultaneously in tension and in shear.

Keywords: concrete; NDT; pull-out test; tension; shear; pressure gage; total load; calibration chart.

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239. STOKES, V. Proposed course outline for teaching non-destructive testing in vocational and technical schools and junior colleges", Amer. Soc. Nondestr. Testing; Materials Evaluation, July, 1972, pp. 20A - 42A.

Proposed course of instruction (2 years):

A. The origin and significance of discontinuities;
B. Liquid penetrant method;
C. Magnetic particle testing;
D. Eddy current testing;
E. Ultrasonic testing;
F. Radiographic testing.

Keywords: as above.

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240. PETERSONS, N. "Recommendations for estimating quality of concrete in finished structures"; RILEM, Matériaux et Constructions Essais et Recherches, Vol. 5, No. 25, Jan./Feb., 1972, pp. 379 - 397.

These recommendations are supposed to guide an engineer in selection and use of the procedures which he should adopt when he is required to estimate the quality of concrete in finished structures. These recommendations are not intended to be a standard or a code of practice.

Keywords: concrete strength; drilled cores; dynamic methods; combined ultrasonic tests; pulse velocity; surface hardness; radioactive methods.

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241. PROCEQ, S.A., "Baustoff-Prüfhammer, Modell P und Modell PT, Gebrauchsanweisung" (Materials Testhammer, Model P and Model PT - Guidelines for use); 16 p. brochure, Proseq SA, Basel and Zürich, Jan. 1972.

Pendulum type test hammer, designed by E. Schmidt, Basel, Switzerland, for use on low strength and cellular concrete, having a 0.09 mkg impact force. (Normal Schmidt rebound test hammer has a 0.225 mkg impact force). Model P is for concrete with 50 to 250 kg/cm^2 compressive strength; hammerhead is 20 mm dia. Model PT is for extremely soft material with 5 to 80 kg/cm^2 strength; hammerhead is larger - 40 mm dia.

Keywords: pendulum impact test hammer; low-strength concrete testing; Schmidt test hammer.

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242. REHM, G., WAUBKE, N.V., NEISECKE, J., "Ultraschall - Impulstechnik für Fertigteile, Abschlussbericht" (Ultrasonic impulse technique for precast concrete products). A research report for the Technical University of Braunschweig, Germany, Nov. 15, 1972, 67 pp., incl. 16 ref. in German, English and French.

This is a research contract sponsored by the Federal Ministry for Housing and City development, in W. Germany. (Az.: 16-800171-15). The research program was carried out at the Institute for Construction Materials and Reinf. Concrete Construction, at the Techn. University of Braunschweig. It shows different types of

equipment for ultrasonic pulse velocity measurements to determine concrete quality, hydration progress and crack development.

Keywords: NDT; concrete strength; cracking; cement hydration; pulse velocity; transducer types.

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243. RILEM (International Union of Testing and Research laboratories for Materials and Structures), "Rilem Recommendation - NDT 1: Testing of concrete by the ultrasonic pulse method"; UDC 620.179.16: 666.972: 69.001.3). December, 1972, 10 pages.

The RILEM/NDT 1 Recommendation relative to tests of concrete by the vibration method was drafted by R. Jones and I. Facaoaru at the request of RILEM Comm. on NDT and approved by the latter at its meeting in Varna (Bulgaria) Sept. 2 - 6, 1969. The text, published in Materials & Structures - Research and Testing, Vol. 2, No. 10, July-August 1969, was then a tentative Recommendation. After three years of probationary period, it is now a valid RILEM Recommendation.

Keywords: NDT, vibration method; U/S pulse velocity.

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244. USSR, "Nondestructive methods for the quality control of reinforced concrete", GOSSTROI - NIIZhB, Izdatelstvo literaturi po Stroiteletvu, Moscow, 1972; Book, 127 pp. (in Russian).

A compilation of 11 papers, covering different practical applications of NDT in concrete quality control of precast products:

1) "Developments in NDT methods for quality control of reinforced concrete structure", G.I. Berditchevskij, V. Klevtsov.
2) "Evaluation of strength, crack-resistance and deformation of structures by the results of NDT", G.I. Berditchevskij, V.A. Tarshish and N.A. Markarov.
3) "Precision of ND quality control and strength determination by the results of NDT", V.A. Klevtsov, M.G. Korevickaja.
4) "Increased reliability in strength determination of concrete structures", G.V. Sizov.
5) "Effect of the stability of concrete mixes on strength determination accuracy by the NDT methods", A.A. Grebenick.
6) "Strength of heated and cooled concrete. Ultrasonic control of concrete product during curing", N.A. Markarov, et al.
7) "Indirect determination of structural parameters for reinforced concrete products by correlation of diff. methods", S.A. Ivazjan and A.A. Tamarin.
8) "Effect of prestressing magnitude on evaluation of precast structural parts", H.A. Markaroff, et al.
9) "Reliability control of tendon strand anchoring at the manufacturing of prestressed concrete struct. parts", V.P. Safronov and H.A. Markaroff.
10) "Use of ultrasonic pulse method to determine the bond loss between reinf. steel and concrete", V.A. Klevtsov, et al.
11) "Use of instrument IZS to determine the location and cover thickness of reinforcement steel", V.A. Klevtsov and V.A. Grebennikov.

Keywords: NDT of concrete; concrete physical parameters; crack resistance; deformations; strength determination; precast concrete products; strand bond in prestressing; strand bond rupture; ultrasonic pulse velocity test method.

245. USSR, State Standards GOST 17623 -24 and -25, 1972, "Concrete and reinforced concrete structures and products - Non-destructive methods for quality control", Izdatelstvo Standartov, Moscow, 1972, 44 pp. (in Russian).

These standards cover:

1) GOST 17623-72, for heavy, lightweight and cellular concrete. Density determination by isotope method for concrete mixes and for hardened concrete products;
2) GOST 17624-72, for heavy and lightweight concrete. Ultrasonic method of strength determination by measuring ultrasonic pulse velocity and correlating it with a calibrating curve for compressive strength;
3) GOST 17625-72, for reinf. concrete structures and precast units. Determination of thickness, and reinforcement steel location and concrete cover thickness.

Keywords: NDT; density measurements; radioactive methods; ultrasonic pulse velocity; detection of reinf. in concrete; thickness of steel covering.

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246. USSR, "Guidelines for concrete strength control in structures by using mechanical testing equipment", Nauchno-izsledovatelnij Institut betons i zhelezobetona (NIIZHB - GOSSTROI), Izdatelstvo Literatui po Stroitelstvu, Moscow, 1972, 56 pp. (in Russian).

Described are several types of test equipment and their uses:

a) Indentation on concrete surface by hammer NIIMOSSTROI, spring-activated CHPA, pendulum hammer DPG-4, sclerometer KM;
b) Schmidt rebound hammer, Types N, NR, L and M;
c) Pull-out test GPNB-5;

d) Static loading by a hydraulic press indentation, apparatus NIIZhB with modification CRP-9-300; ORP-4-300; OMP-2-250 and RPM-5.

Keywords: concrete compressive strength; indentation; rebound; pull-out; static pressure.

1973

247. DRYSDALE, R.G., "Variation of concrete strength in existing buildings", Magazine of Concrete Research, Vol. 25, No. 85, Dec. 1973, pp. 201 - 207.

Ultrasonic pulse velocity measurements from 1145 concrete columns in 15 existing buildings were used as data to indicate variability of concrete strength. The factors considered were: differences between columns, location within column height, column size, etc. Coefficients of variation of concrete strength are used to indicate control of quality. It is suggested that information obtained illustrates the value of such measurements for inspection purposes.

Keywords: NDT; concrete strength; columns; pulse velocity; quality control; statistical evaluation; coefficient of variation.

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248. IDDINGS, F.A., MILLER, L.W., Jr. and PEPPER, C.E., "A rapid field determination of cement content". Paper presented at the 9th Symposium on Nondestructive Evaluation, San Antonio, Texas, April 25 - 27, 1973.

Work sponsored by U.S. Dept. of Transportation and FHWA. Activation analysis using Cf-252 neutron sources has been found to be a rapid and accurate method for determining cement content in soil mixtures and in concrete. It is a simple operation and

adaptable for field use. Results provide a precision of ± 5% of the amount of cement.

Keywords: cement; concrete; Cf-252 neutron source; radioaction; soil mixture.

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249. KOREVICKAJA, M.G., et al., "Application of NDT methods of products quality control at prefabricated housing combinat (DSK) in Wilnius, Lithuanian SSR", Journal, Beton i Zhelezobeton, No. 8, 1973. Publisher - Stroiizdat Moscow, pp. 35 - 36 (In Russian).

The NDT methods are being used basically to determine the strength of concrete. However, strength is not the only property indicating the quality of concrete. At the prefab. housing combined plant in the Wilnius DSK a control system is being used, which include ND testing of several product parameters such as strength of concrete, location and diam. of reinforcement bars, thickness of concrete cover, and dimensions of product, based on GOST Temp. guidelines for the NDT SN 417-70.

Keywords: NDT; concrete strength; cover thickness; reinf. bar diameter; geometrical dimensions of products.

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250. LUXMOORE, A., "Holographic detection of cracks in concrete". Non-Destructive Testing (IPC Science and Technology Press, England), Vol. 6, No. 5, pp. 256 - 264, Oct. 1973.

The author describes the application of holography on concrete and electronic recording of its information. The holographic results were compared with penetrating dyes, X-ray radiography and eddy current testing, and were found to be just as reliable.

Keywords: concrete; cracks; detection of cracks; eddy current testing; holography; penetrating dyes; X-ray radiography.

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251. NWOKOYE, D.N., "Prediction and assessment of concrete properties from pulse velocity tests". Magazine of Concrete Research, Vol. 25, No. 82, 1973, pp. 39 - 46.

A study on feasibility of applying multi-phase theory to the interpretation of pulse-velocity tests, to examine the property and behaviour of mortars and cement-paste phases in concretes. It was found that the stiffness constant is a better index for the assessment of the dynamic modulus of elasticity than the pulse velocity. Propagation velocity through the cement-paste phase gave better correlation with compressive and rupture strength than the pulse velocity through concrete, which is influenced by the type of aggregate.

Keywords: concrete properties; cement paste; density; dynamic modulus of elasticity; non-destructive testing; propagation velocity; stiffness constant; ultrasonic pulse velocity; Young's modulus.

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252. RAJAGOPALAN, P.R., PRAKASH, J. and NARASIMHAN, V. "Correlation between ultrasonic pulse velocity and strength of concrete", Indian Concrete Journal, Vol. 47, Nov. 1973, pp. 416 - 418.

This paper discusses the correlation between ultrasonic pulse velocity and compressive strength of concrete. Simultaneous measurements of pulse velocity and compressive strength made on 15-cm cubes at ages from one day to 28 days indicate that there is a linear correlation. It is shown that tests at age 7 d. are more reliable for assessing compressive strength on the basis of pulse velocity measurements than tests at 28 days.

Keywords: concrete; compressive strength; pulse velocity; concrete mixes; concrete age; empirical correlation.

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253. ROSE, J. and MORTIMER, "Elastic wave analysis in nondestructive testing". This is Part II of a two-part paper presented at the National Fall Conference of the American Society of Non-destructive Testing, Oct. 18 - 21, 1971 in Detroit, Mich. (Part I appeared in the Nov. 1972 issue). Materials Evaluation, Vol. 31, March 1973, pp. 33 - 38.

This paper demonstrates that analytical wave propagation procedures can be useful in ultrasonic signal interpretation analysis. The usefulness of employing elastic wave computer codes in NDT analysis is discussed. The work discusses dispersion and points out its importance in the NDT of tubes, rods, plates, and composite materials.

Keywords: analysis of elastic waves; dispersion analysis; elastic waves computer codes; ultrasonic signal; tubes; composite materials; wave propagation.

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254. USSR, "Non-destructive quality control of concrete and reinforced concrete", Third All-Union Conference held Oct. 1973, in Wilnius, Lithuanian SSR. A series of articles from this conference is published in the journal Concrete and Reinforced Concrete (Beton i zhelezobeton), No. 10, 1973, Stroiizdat, Moscow (in Russian).

1) State of art and problems in quality improvement of reinforced concrete products and structures", Mikhailov, V.A., Nilender, Y.A., Mikhailov, K.V., Gorshkov, A.M., pp. 2 - 3.

2) "Quality control of precast concrete structures", Dorf, V.A. et al, pp. 4 - 5.
3) "Non-destructive methods for quality control of rein-forced concrete structures in Lithuanian SSR", Kudzes, A.P. et al., pp. 5 - 7.
4) "Non-destructive methods for concrete quality control in energy construction", Yakovlev, A.I., Lapnik, V.G., pp. 7 - 10.
5) "Non-destructive methods for concrete and reinforced concrete control at the plants of the USSR Construction Ministry", Terekhov, S.M., Nesterenko, I. A., pp. 10 - 12.
6) "Concrete quality control by ultrasonic impulse methods", Noghin, S.I., pp. 12 - 14.
7) "Ultrasonic methods for quality control of reinforced concrete pipes and railway ties, Wainshtok, I.S. et al, pp. 14 - 16.
8) "Radiometric methods for concrete and reinforced concrete structures and products control", Vorobjev, V.A. et al, pp. 17 - 19.
9) "Concrete strength determination by pull-out bar test", Volf, I.V., pp. 20 - 22.
10) Instruments for measurement of ultrasonic velocity in building materials", Salop, G.A., Timoshenko, L.A. and Serikov, Ya. A., p. 26.

Keywords: NDT of concrete; concrete quality control; correlation of physical parameters; indirect strength determination of concrete; pull-out tests; radiometric test methods; ultrasonic pulse velocity measurements.

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255. WANE, J.C.K., AUSKERN, A. and HORN, W., "Determination of resonant vibration frequency of concrete by acoustic impact technique", Journal of Testing and Evaluation, Vol. 1, No. 4, July 1973, pp. 291 - 294.

A simple technique based on the acoustic impact method is described for measuring the longitudinal, transverse and torsional vibration modes of concrete. The results are in excellent agreement with the standard ASTM C 215 - 60 procedure of forced vibration for determining the resonant frequencies. It is suggested that the acoustic impact method be considered an alternative to the standard technique.

Keywords: acoustics; impact; concrete; vibration; resonant frequency - longitudinal, transverse, torsional.

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256. ZURBRICK, J.R., "Direct nondestructive prediction of engineering properties", Journal of Testing and Evaluation, Vol. 1, No. 1, Jan. 1973, pp. 13 - 23.

Quantitative nondestructive evaluation provides the means for directly predicting engineering properties of materials on individual components. Through proper problem definitions, the working concept of material - energy interaction, and multifunctional/multivariable relationships, a complex material system can now be characterized in terms of both bulk and constituent properties as they actually exist in the finished product.

Keywords: NDT; mechanical properties; E modulus; ultrasonic frequencies; bonding strength; adhesive bonding; surface energy.

1974

257. BRITISH STANDARDS INSTITUTION, "Recommendations for non-destructive methods of test for concrete - The measurement of the velocity of ultrasonic pulses in concrete", BS 4408, Part 5, 1974.

This standard is concerned with the measurement of the velocity of transmission of longitudinal ultrasonic pulses through concrete; it is hoped that better understanding of the measuring technique will result from its use. It includes some recommendations on the interpretation of test results and their correlation with elastic modulus and strength test.

Keywords: concrete; NDT; compressive strength; cracks; deterioration; pulse velocity; pulse generation; length of pass; travel time; ultrasonic pulses.

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258. DSENIS, V.V., DONSKOI,V.Z., WASILJEV, V.G. and KONDRATENKO, E.A., "Quality control of concrete products by ultrasonic surface waves", Beton i Zhelezobeton, Gosstroiizdat, Moscow, No. 6, 1974, pp. 19 - 20 (in Russian).

At the SDK-2, Leningrad, tests were made on precast concrete housing wall panels, for quality control purposes applying surface type ultrasonic wave method using transducers with point contact and exponential wave guide. This type of transducer is preferred for surface wave velocity measurements because of good point contact and no need for greasing a flat contact. When panels are cast in cassette forms, only a small strip is exposed.

Keywords: NDT; surface waves; point contact transducers; exponential wave guide.

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259. LUISONI, C.J. and SOMENSON, H.M., "Nondestructive test for determining compressive strength of concrete", ACI Journal, March 1974, pp. 132 - 133.

The method presented here may be considered non-destructive, because of the localized fracture of concrete under high compressive stresses applied to an extremely small area. This test does not destroy the structural element, but does destroy the material that is analyzed. As the fracture is due to shearing stresses, it occurs practically without deformation on this affected region. It is a brittle-type fracture when the ultimate load is reached.

Keywords: concrete; compressive strength; compr. stresses; brittle type fracture; shearing stresses; NDT method.

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260. MALHOTRA, V.M., "Evaluation of the Windsor probe test for estimating compressive strength of concrete", RILEM Bulletin No. 37, Jan./Feb., 1974, pp. 3 - 14.

The probe test is of a ballistic nature. It is performed by firing a 82.6 mm alloy-steel probe into hardened concrete. The exposed length of the intruded probe is recorded and related to the compressive strength of concrete. The effect of the aggregate hardness is accounted for by using different calibration charts for minerals having different Mohs hardness. The Windsor probe will not yield absolute values for strength of concrete, but indicates the relative strengths in the same structure or compares strengths of concrete in different structures.

Keywords: ballistic probe; compressive strength of concrete; driving unit; hardness test; Windsor probe; penetration test.

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261. NATESAN, S.C., "A correlation between ultrasonic pulse velocity and strength of concrete", Indian Concrete Journal, Vol. 48, No. 7, July 1974, 207 pp.

The author has discussed critically the empirical equation between the ultrasonic pulse velocity and the compressive strength of concrete, as derived in Paper No. 252 above. It is stressed that an accurate prediction is possible only if the equation is used within the particular range of test data into which it is fitted. To be considered are the effects of different type of aggregate, mix proportion; moisture content, reinforcement and existing stress in concrete. Enclosed also is a reply by the author of paper No. 252.

Keywords: concrete; compressive strength; pulse velocity empirical equation; correlation.

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262. POCHTOVIK, G.J., "Introduction of the non-destructive quality control in concrete and reinforced concrete construction", Report of Third All-Union conference held in Wilnius, Lithuanian SSR, Oct. 1973; Journal of Concrete and Reinforced Concrete (Beton i Zhelezobeton) No. 2, 1974; pp. 42 - 43; Stroiizdat, Moscow (in Russian).

This conference was attended by 250 experts in concrete from 10 republics as well as from abroad. Presented were 36 papers, most of which are publ. in Beton i zhelezobeton No. 10, 1973 (see ref. No. 254.). Based on collected field experiences, several recommendations were advanced for inclusion of ND testing methods in the state standards such as GOST 17623, GOST 17624, GOST 17625-72 and Guidelines for evaluation of NDT results in SN 417-70.

Keywords: concrete NDT; USSR All-Union Conferences; 1960 - 1963; control of concrete products at plants; quality control; concrete properties; collaboration between concrete research organizations.

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263. STURRUP, V.R. "Pulse velocity as a measure of concrete compressive strength". Presented at the Canadian Capital Chapter of the ACI in Ottawa, Dec. 5 - 6, 1974, 26 pp.

The compressive strength of concrete has been the index of quality and acceptance for many years. This property is generally determined by compressive tests on standard test cylinders. That the results of such tests relate to the strength of concrete in the structure is subject to much controversy. The purpose of this paper is to review one of the new test methods (pulse velocity) as a non-destructive method for determining concrete strength without relating it with other physical parameters of concrete. The data were obtained from tests performed by Ontario Hydro.

Keywords: concrete; compressive strength; pulse velocity; composition of concrete.

1975

264. ASTM, "Tentative method of test for penetration resistance of hardened concrete", Book of ASTM Standards, 1975, Part 14; Designation C 803 - 75 T.

This method covers the determination of the resistance of hardened concrete to penetration of a steel probe energized by a driving unit delivering a stated amount of energy. The penetration resistance of the concrete is determined by measuring the exposed portion of probes of stated length. This method may be used to assess the uniformity of concrete in situ and to delineate areas of

poor quality or deteriorated concrete in structure. It is not intended as an alternative for strength determination of concrete.

Keywords: NDT; concrete hardness; controlled powder-actuated device; driving gun; steel probe; Windsor probe.

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265. ASTM, "Tentative method of test for rebound number of hardened concrete", Book of ASTM Standards, 1975, Part 14; Designation C 805 - 75 T.

This method covers the determination of a rebound number for hardened concrete using a spring driver steel hammer. The rebound number may be used to assess the uniformity of concrete in situ, to delineate areas of poor quality or deteriorated concrete in structure. It may indicate changes with time in characteristics of concrete. It provides useful information in determining when forms and shoring may be removed. This method is not intended as an alternative for strength determination of concrete.

Keywords: NDT; calibration curve; concrete strength; rebound number; spring hammer; surface hardness; Schmidt test hammer.

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